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TEMPORARY STORAGE AND ULTIMATE DISPOSAL OF OIL RECOVERED FROM SPILLS IN ALASKA

FINAL REPORT

DECEMBER 1975

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U.S. DEPARTMENT OF TRANSPORTATION
UNITED STATES COAST GUARD
OFFICE OF RESEARCH AND DEVELOPMENT
WASHINGTON ,D.C. 20590

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16. Abstract

This report identifies alternative methods for temporary storage and ultimate disposal of oil recovered from postulated spills in Alaska. Seven representative sites felt to be future areas of high spill potential are evaluated with respect to storage and disposal of spills ranging in volume from 100 to 50,000 barrels. The types of spills considered are crude oil, distillate fuel oil, residual fuel oil and gasoline. The potential adverse effects of the Alaskan environment on handling, storage and ultimate disposal of oil spills are compared to more temperate climates is also discussed.

Two distinct requirements for storage were identified: immediate (from hours to days) and temporary storage (up to one year). It was concluded that all temporary storage should be on land. Portable storage containers presently available from commercial interests and the use of natural terrain features are evaluated from the range of spill sizes and types. Alternatives evaluated for the ultimate disposal of oil include both in-situ burning and burning in conventional burners and incinerators. In-situ burning emerged as the preferred method of disposal at virtually all sites evaluated. On scene observation of the December 1975 DIESEL SPILL AT PRUDHOE BAY ALASKA and the disposal techniques used are included as APPENDIX C.

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METRIC CONVERSION FACTORS

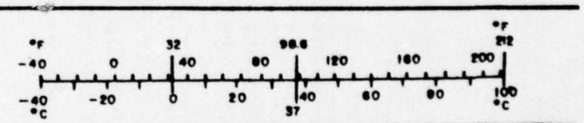
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



FINAL REPORT

TEMPORARY STORAGE AND ULTIMATE DISPOSAL OF OIL RECOVERED FROM SPILLS IN ALASKA

TO

UNITED STATES COAST GUARD
WASHINGTON, D. C.
CONTRACT DOT-CG-23223-A
TASK 19

December 1975

P. L. Peterson
Project Manager

PACIFIC NORTHWEST LABORATORIES
a division of
BATTELLE MEMORIAL INSTITUTE
RICHLAND, WASHINGTON 99352

PREFACE AND ACKNOWLEDGEMENTS

This report has been prepared for the United States Coast Guard to evaluate methods and equipment for the temporary storage and ultimate disposal of oil products recovered from spills in the Arctic and sub-Arctic regions of Alaska.

The report was prepared under Contract DOT-CG-23223-A to the Columbus Laboratories of the Battelle Memorial Institute. The work was performed by both the Pacific Northwest and Columbus Laboratories of Battelle. Battelle-Northwest participants in the Study included P.L. Peterson, program manager; J.B. Duffy and M.M. Orgill. The Columbus Laboratory program manager was R.E. Barrett and the Columbus contribution in the primary areas of burning and incineration were written by R.A. Yano, with contributions given by A.A. Putnam, R.E. Barrett, H.E. Engdahl, H.R. Hazard and A.E. Weller.

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FINAL REPORT

Contract DOT-CG-23223-A

TASK 19

TEMPORARY STORAGE AND ULTIMATE DISPOSAL OF OIL RECOVERED FROM SPILLS IN ALASKA

to

United States Coast Guard
Washington, D. C.

from

BATTELLE
PACIFIC NORTHWEST LABORATORIES
RICHLAND, WASHINGTON 99352

October 1975

1.0 INTRODUCTION AND FRAMEWORK

1.1 NATURE OF THE PROBLEM

The U. S. Coast Guard has the responsibility for preventing and controlling oil spills in and along the coastal waters of the United States from authority granted by the Water Pollution Control Act. The coastal waters of arctic and sub-arctic Alaska are in the direct area of Coast Guard responsibility. Inland areas such as the North Slope are also of interest because the Coast Guard's presence in Alaska will likely necessitate some form of Coast Guard response to all oil spills in the state, regardless of location.

Cleanup and disposal of oil spills are the responsibility of the person or persons causing the discharge. If the responsible party is taking appropriate action, the role of the Coast Guard is relatively passive, consisting primarily of monitoring progress and providing advice. In the event that the responsible party cannot be determined or does not take appropriate action, the Coast Guard institutes the necessary cleanup and disposal actions.

The requirement for direct Coast Guard response or active assistance to the responsible party is more probable in Alaska than in similar spill situations in the "lower 48" states. The geographic expanse, remoteness and underdeveloped nature of Alaska minimize the probability that the required equipment, personnel and facilities will be available in the immediate area of the spill. Logistic support will be a prime factor in all potential spill areas. The Coast Guard has the only large and established air-sea emergency response capability within Alaska. Direct Coast Guard participation in the event of marine spills is highly probable due to the requirements for very rapid response and a general lack of marine transportation systems within the state.

The attendant problems of containment, recovery, storage and disposal associated with oil spillage will vary widely in Alaska, depending upon

1) the volume and type of petroleum products released,
2) the geographic and environmental setting of the spill and
3) the availability of equipment and personnel to conduct the spill cleanup.

The potential for crude oil production from the Alaskan mainland and adjoining continental shelf is truly immense, in both volume and areal extent. Developed fields in Cook Inlet and the probable reserves in the Prudhoe Bay field (estimated at 10 billion barrels by industry) will provide approximately 10% of United States crude oil demands in the early 1980's. The preliminary assessment of the reserves in other areas such as the Naval Petroleum Reserve #4 (NPR 4) on the North Slope and the presence of promising geologic formations on virtually all of the accessible continental margins surrounding the Alaskan mainland bespeak a potential for eventual production several times the 2-3 million barrels per day projected for the Trans-Alaska Pipeline System (TAPS). Declining domestic production, uncertainties in the future reliability of foreign imports, the "Project Independence" goal for United States energy self-sufficiency by the mid-1980's, and recent acceleration of Outer Continental Shelf (OCS) schedules for sales in new areas are indicators that Alaskan petroleum resources will be developed within a shorter time frame than previously assumed.

A recent Outer Continental Shelf (OCS) tentative lease sale schedule includes sales of tracts in the following areas of Alaska before the end of 1978:[1]

- Lower Cook Inlet
- Gulf of Alaska (eastern)
- Bering Sea (St. George)
- Gulf of Alaska around Kodiak
- Beaufort Sea
- Outer Bristol Basin (Bristol Bay)
- Bering Sea (Norton Basin)
- Gulf of Alaska (Aleutian Shelf)
- Chuckchi Sea (Hope Basin)

The areas tabulated above encompass the coastline of the Alaskan mainland, thus extending the marine waters potentially threatened by oil spillage to virtually the entire coastal margin of the mainland. Further inland areas will similarly be threatened by oil spillage either by development of oil fields or establishment of new transportation routes (pipelines).

The major oil spill threat in Alaska is expected to become and remain that related to crude oil development, production and transportation. However, expanding construction activity and industrial development will continually increase the threat of releasing refined petroleum products. The bulk of Alaskan crude oil will continue to be exported for refining outside the state in the forseeable future, as it has in the past.

The frequency and volume of oil spillage are commonly predicted by correlation to ongoing exploration, production, transfer and transportation activities; which can in turn be projected into the future on the basis of past development. Oil spill statistics from past petroleum activities in the United States and other countries are commonly used to predict oil spill frequency and volume resulting from future Alaskan development. Such statistics are virtually the only source available. However, it must be remembered that these statistics were primarily derived from operations in more temperate climates and, as such, may have limited relevance to arctic operations. Prediction of oil spills in Alaska is fraught with

uncertainty because of the extremely limited past experience with crude oil production (Cook Inlet). Also, the scant number of extablished transportation systems for either crude or refined products, and worldwide lack of experience in arctic petroleum development and production. Most areas of Alaska will be classified as frontiers of petroleum development.

The potentially hostile environment and lack of development in Alaska necessitates a re-evaluation of priorities established for oil spill response in temperate climates. Many of the options for storage and disposal of recovered oil do not exist in the Arctic. The widespread availability of equipment and facilities and complex technology developed for coping with spills in the "lower 48" states does not exist or may have little application in the Arctic. Standard equipment and systems must be simplified or specially adapted for use in the Arctic. Logistics is a severe problem throughout most of the state. It must be assumed that all equipment, personnel and support functions necessary to conduct cleanup and disposal operations at any specific site will have to be brought to the site from locations up to one thousand miles away. Improvisation, which is so common in temperate area spills, is nearly impossible throughout the arctic and most sub-arctic regions of Alaska because of the remoteness and general lack of nearby equipment, materials and facilities.

The most serious present limitation to the evaluation of systems and procedures for handling storage and disposal of recovered oil is a general lack of knowledge regarding the engineering properties and behavior of petroleum products in the arctic environment. Limited testing has been conducted with Prudhoe Bay crude and some information is available from oil spills in other arctic regions of the world (primarily Canada and the Scandinavian countries). However, the bulk of oil fields in Alaska have yet to be developed, so knowledge regarding the behavior of many Alaskan crudes must await the development. Crude oils with pour points above approximately 20°F may require completely different systems for handling, storage, and disposal than those which remain fluid in the arctic environment.

1.2 CONDITIONS UNIQUE TO ALASKA

Constraints on the handling, temporary storage and ultimate disposal of petroleum products recovered from Alaskan spills will exist that render many of the conventional equipment and procedures developed for more temperate regions ineffective or greatly reduce the efficiency. The conditions which produce the constraints must be accommodated and can sometimes be used advantageously if recognized and worked with rather than avoided. Numerous oil spills have occurred in Alaska, but relatively few spills have been recovered. Coast Guard experience with storage and disposal of recovered oil in Alaska is almost totally lacking. Difficulties encountered in spill response under arctic or sub-arctic conditions such as the spill at Cold Bay, Alaska in March of 1973[2] indicate that Alaska should be considered as a special case within Coast Guard planning for the prevention and control of oil spills at least until further experience proves otherwise. Consideration as a special case is meant to suggest that development of equipment and procedures be conducted independently for arctic conditions, rather than by adaptation of conventional systems.

The uniqueness of Alaska with respect to storage and disposal of recovered oil stems primarily from the northern location and resultant arctic and sub-arctic environments. However, the immense areal extent, lack of population and resultant development, and rather concentrated Coast Guard presence make all types of emergency response operations problematic, particularly in the Arctic. Many, if not most, of the environmental extremes for which Alaska is noted occur seasonally at selected locations in "lower 48" states. The constraints imposed by the inhospitable aspects of the Alaskan environment are more normally attributable to habitual occurrence, extended duration, or simultaneous combination of several undesirable effects as compared to singular events in temperate regions.

Some of the more significant factors considered unique or exaggerated in Alaska and the resultant constraints on oil spill response operations are tabulated below:

Arctic and sub-Arctic Environment

Extreme cold - Temperatures down to -70°F reduce efficiency of personnel up to 90%; drastic alteration of the properties and behavior of petroleum products; causes failure or non-performance of equipment and materials.

Winter darkness - Limited extent or nonexistence of daylight severely hampers field operations and reduces personnel efficiency.

Wind - Winds in excess of 100 knots are not uncommon along coastlines which can result in structural damage and greatly reduce wind chill factors.

Oceanographic- Extreme tides (up to 40 feet in Cook Inlet), seas (primarily in Gulf of Alaska), and sea ice can severely hamper spill handling; sea ice must be considered as debris.

Ecological - Abundance of fish and wildlife accentuates the potential damage from spills, relatively sensitive vegetation (tundra) readily damaged by field operations; large animals such as bears can destroy storage systems (notably pillow tanks).

Permafrost - Seasonal instability of sediments containing moisture complicates travel overland and virtually precludes sound footings for structures.

Geographic and Physiographic

Vast expanse - A land area equal to approximately 20% of the continental United States, a similar area of continental shelf and approximately 34,000 miles of coastline seriously complicate logistics; air travel almost mandatory to arctic locations.

Lack of ports & harbors - The combination of extremely shallow coastal waters and virtually complete lack of suitable ports and harbors along the Bering Sea and arctic coastlines complicates shoreside access and logistics.

Low shorelines	- Practically the entire Bering Sea and arctic coastline is low-lying and therefore susceptible to storm surges and wind-driven pack-ice; accessible areas of the Gulf of Alaska are similarly susceptible to tidal waves (tsunamis) or flooding; major cities that have been inundated during the past 15 years include Kodiak, Seward, Nome and Cordova.

<u>Industrial Development</u>

Remoteness	- Population and industry concentrated in areas of south-central mainland and Southeast Alaska; few facilities available in Arctic or westward; population centers not necessarily in areas of high oil spill potential.
Lack of transportation systems	- Virtually no roads in coastal areas, overland travel difficult in summer, air transport almost mandatory which restricts size and weight of equipment.
Lack of widespread Coast Guard facilities	- Coast Guard concentrated in Southeast Alaska and south-central portion of mainland which necessitates response over long distances.
Lack of communications systems	- Established communications systems inadequate or non-existent.

<u>Petroleum Industry Development</u>

Limited previous experience	- Development restricted to Cook Inlet, limited arctic experience.
Potential for rapid expansion	- Enormous probable reserves will lead to rapid development of new fields and modes of transportation which complicates planning for prevention and control of future spills.

Varied locations of new fields - Promising geologic formations virtually encompass the entire mainland opening nearly one million square miles to development which severly affects logistics and planning; properties of crude oils unknown.

1.3 FRAMEWORK OF THE STUDY

Temporary storage and/or ultimate disposal of oil recovered from spills can be accomplished by any of the alternative approaches indicated in Figure 1-1. Practical options available will depend to a great extent on the methods used for recovery, the type of petroleum product, and the geographical and environmental setting of the spill.

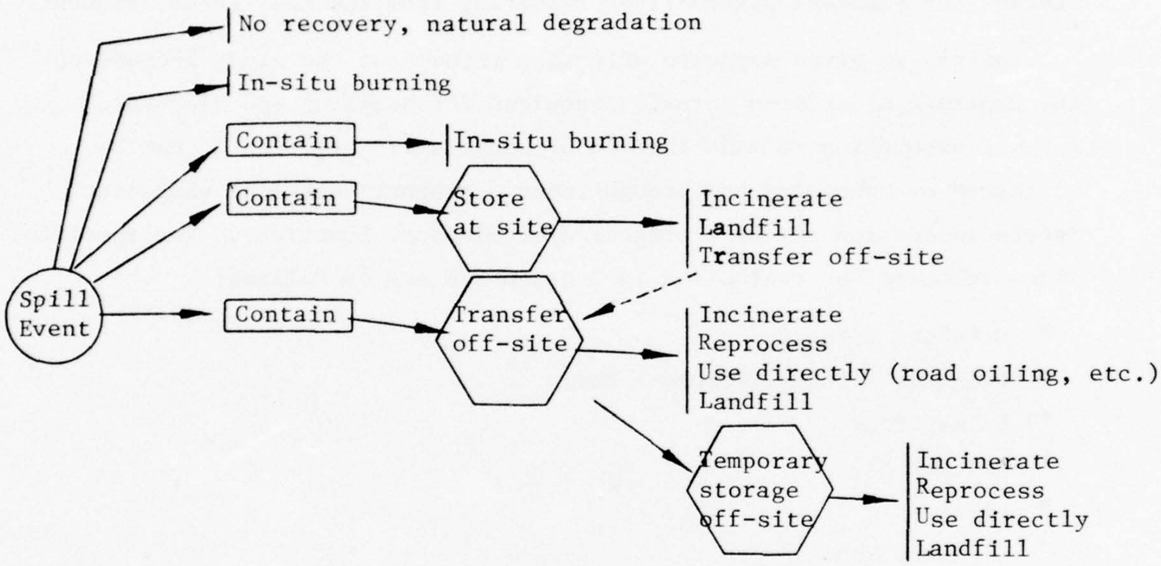

FIGURE 1-1. ALTERNATIVE APPROACHES FOR DISPOSAL OF OIL SPILLS

The objective of the present study is to determine the preferred method for disposal of recovered oil and oil-soaked debris for areas of high spill potential in Alaska. The objective is accomplished by evaluation of alternative methods for storage and disposal of a range of spill sizes and types at selected sites of high oil spill potential within the state. The study draws heavily from three previous studies conducted by Battelle for the Coast Guard related to storage and disposal of spills in temperate regions,[3] analysis of spill potential associated with future Alaskan oil production,[4] and the attendant logistic problems to selected sites within Alaska.[5] The scope of this study included only a superficial evaluation of ecological and environmental effects of oil spills and the equipment or techniques for handling, storage and disposal of the spills.

The types of spills considered for each selected location are crude oil, distillate fuel oil, residual fuel oil and gasoline. Spill volumes of 100, 1,000, 10,000 and 50,000 barrels are evaluated for each location. Methods of storing and ultimately disposing of recovered oil are discussed generically in Section 4.0 and subsequently evaluated for specific sites (Section 5.0). A discussion of oil properties and handling constraints is included in Section 4.0 because of the potentially profound effects on storage and disposal alternatives resulting from the Alaskan environment.

Debris is given separate attention throughout the study because of the separate procedures normally required for handling and disposal. A basic assumption is made that an offshore spill has been or can be contained or recovered and brought near a support vessel or shoreline before initiation of the storage and/or disposal functions. The specific sites selected for evaluation in Section 5.0 are as follows:

- Offshore Yakutat
- Lower Cook Inlet (Kachemak Bay)
- Unimak Pass
- Kvichak Bay
- Umiat
- Offshore Nome
- Offshore Prudhoe Bay

1.0 REFERENCES CITED

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3. Kim, B. C., et al., "Support Systems to Deliver and Maintain Oil Recovery Systems and Dispose of Recovered Oil," U. S. Coast Guard Report No. CG-D-56-74, January 1974.

4. Swift, W. H., et al., "Geographical Analysis of Oil Spill Potential Associated with Alaskan Oil Production and Transportation System," Department of Transportation, U. S. Coast Guard Report No. CG-D-79-74, February 1974.

5. Peterson, P. L., et al., "Logistic Requirements and Capabilities for Response to Oil Pollution in Alaska," U. S. Coast Guard Report No. CG-D-97-75, March 1975.

2.0 SUMMARY AND CONCLUSIONS

The most promising approach to ultimate disposal of oil recovered from spills in Alaska was found to be in situ burning for all representative sites evaluated, with the possible exception of Lower Cook Inlet where adequate equipment and facilities for storage and disposal and spill access are likely to exist. The temporary air pollution from in situ burning was judged to have far less ecological consequences than the potential damage due to spills that cannot be completely controlled or are subsequently re-released by storage system failure. Controlled burning of recovered oil at the spill site is the preferred alternative in the event that the spill will not burn without promotion or in cases where personnel or equipment are in danger from uncontrolled burning. In situ or controlled burning of gasoline is not recommended unless the potential ecological consequences of uncontrolled release are known to be severe. Gasoline will evaporate fairly rapidly even under arctic conditions if on the surface. Extremely cold conditions which retard evaporation of gasoline should permit safe in situ burning. However, until procedures are developed for remote handling of gasoline spills, no type of burning is advisable.

Spills which cannot physically or safely be burned in situ must be at least temporarily stored until means of disposal become available. The cold temperatures common in the Arctic year round and in the sub-Arctic seasonally are expected to cause most crude oils and all residual fuel oils to become extremely viscous and in many cases lower the temperature to the pour point before the spill can be reached. Large spills of viscous products, particularly when considerable debris is present, cannot be transferred by conventional pumping equipment. New systems for the transfer of semi-solid petroleum products need to be developed.

2.1 SUMMARY OF METHODS FOR STORAGE OF MARINE SPILLS

Two distinct types of storage requirements were identified:

- immediate storage
- temporary storage

Immediate storage for periods of up to one week take advantage of immediately available equipment or natural features at the spill site such as sea-ice,

floating containers or local vessels of opportunity. Temporary storage can be accomplished by one of three approaches:

- use of existing storage facilities in the immediate vicinity of the spill
- use of natural features such as beaches or small lakes in the immediate vicinity to store recovered oil
- use of portable containers brought to the site.

It was felt that temporary storage devices (for storage over periods up to one year) should always be emplaced onshore. It was concluded that pillow tanks or bladder bags are the most satisfactory portable device for areas of permafrost. Erectable pools similar to commercial swimming pools were felt to be most satisfactory where permafrost does not exist. An upper capacity limit of approximately 2000 barrels for each individual container is recommended.

2.2 SUMMARY OF METHODS FOR STORAGE OF ONSHORE SPILLS

Few differences in approaches to immediate or temporary storage of recovered oil could be identified between onshore and offshore spills in Alaska. This is particularly true during the winter when seasonal ice is present. Access to marine spills is most difficult in the winter when ice is present, while overland access to spills on the tundra is most difficult during the summer. No significantly different approaches to temporary storage were uncovered because it was assumed that marine spills would be stored onshore. Immediate storage of onshore spills has the same options available as marine spills with the exception of marine vessels.

2.3 SUMMARY OF BURNERS AND INCINERATORS FOR ARCTIC OIL SPILL DISPOSAL

Section 4.4 reviews the burners and incinerators which could be used for burning spilled oil and oil-soaked debris in the Arctic. Burners and incinerators which are presently available and also those which could be available with short-term design and development work were examined. The various devices were evaluated with respect to their ability to handle both liquid and solid waste for oil spills ranging in size from 100 to 50,000 barrels. The important results and conclusions of this section are summarized as follows.

(1) Homemade type-incinerators, such as 55-gallon drums with small gas burners, should be sufficient for handling oil spills up to about 100 barrels.

(2) For burning large, liquid oil spills that can be readily collected and pumped, the high capacity NAO, John Zink, or gas-turbine-type burners offer the best approach. The burners can be used to preheat the oil and, with proper control, are smoke-free. The NAO and John Zink burners are presently available while the large gas-turbine burner would require design and development work.

(3) For burning large oil spills with considerable amounts of snow and/or debris, the following incinerators, either presently available or available in the near future appear most promising:

   (a) The all-metal, non-refractory, rotary kiln appears to offer the greatest potential. This system can liquify the oil and water from oil-soaked snow and debris and use the water and oil to provide smoke-free high temperature burning. The Envirogenics Rotary kiln is presently the best available unit. However, it should be investigated and redesigned to reduce size and weight.

   (b) An all-metal, film-cooled wall, portable incinerator, similar to the paper burner developed by Battelle, shows considerable promise for disposing of oil and oil-soaked debris. This lightweight incinerator has been developed with

smoke-free combustion. Design work is needed to expand the size and capacity for handling various size oil spills.

(c) The open pit, smoke-free incinerators, as developed by du Pont and Kenting, show promise for handling even the largest oil spills; however, it will be necessary to significantly reduce the weight of these units. At present, the weight of a unit having pit dimensions 7 ft x 9 ft x 8 ft is over 30,000 lbs.

(d) The trench type incinerator, based on the same working principles as the du Pont or Kenting units, may be practical for certain oil spills. This system consists of an open trench into which oil and debris are shovelled and burned. The oil and debris in the trench could be heated and/or burned using either the flame from an NAO or Zink-type burner or the high temperature exhaust from a portable gas turbine engine. Heated oil could be pumped out of the trench to feed the NAO or Zink-type burner.

2.4 IN-SITU OIL BURNING TECHNIQUES

Section 4.5 reviews the available information on in-situ oil burning and presents various techniques for both the clean and nonclean in-situ burning of spilled oil in the Arctic. The important results and conclusions of this section are summarized as follows.

(1) Information from previous testing in the Arctic indicates that, under most conditions, in-situ burning is an effective method of removing up to 95 percent of spilled crude oil. The remaining 5 percent tar-like residue could be easily raked and disposed of by further burning. Heavy black smoke will be produced. Conditions under which in-situ burning may not be possible include

(a) Oil which has absorbed large amounts of snow will usually not sustain combustion.

(b) Thin oil slicks on water usually will not burn sufficiently. Wicking materials may provide more favorable combustion to sustain burning.

(c) Oil which has aged considerably may not sustain combustion.

(2) Water-spray systems or a properly designed mobile burner are the only techniques available for clean in-situ oil burning.

(3) No test data are available for the in-situ burning of oil with large amounts of debris. It is likely that burning this type waste material will require collection and disposal in some type of incinerator.

3.0 RECOMMENDATIONS

The greatest problem area and lack of available knowledge that arose during the course of the present study was a lack of knowledge regarding the behavior and engineering properties of petroleum products spilled in arctic and sub-arctic regions. Conventional approaches to temporary storage and ultimate disposal of oil recovered from spills are grossly inefficient or may not handle products of high viscosity (approaching 100,000 Saybolt-second units). Similarly, the effects of interaction with ice, snow and cold seawater are not understood for a typical range of spill types and sizes. In situ burning was judged to be the preferred method of disposal for all specific sites evaluated primarily because sufficient information regarding handling and transfer of recovered petroleum product and debris mixtures could not be found. The Arctic is an extremely difficult environment for both men and machines to operate in and simple and straightforward approaches are often the only feasible course of action. In situ burning of spills is certainly a simple and straightforward approach.

3.1 RECOMMENDATIONS FOR TEST AND DEVELOPMENT IN HANDLING AND STORAGE

1) The behavior and engineering properties of petroleum products that have been released into the arctic environment are not fully understood, particularly when ice and snow are present. It is therefore recommended that immediate laboratory and extensive large scale field tests in Alaska be initiated to gain the necessary background knowledge required before effective systems and equipment can be developed. Adaptation of conventional systems may prove futile for spills in which the product is in semisolid form. Particularly desirable are tests with a range of crude oils in which the significant engineering properties such as density, viscosity and the tendency to emulsify or mix with cold seawater, snow, and ice are determined.

2) Certain products released to the arctic environment such as residual fuel oils and certain crudes will rapidly become too viscous to transfer by pumping. It is recommended that high capacity conveying systems (either mechanical or pneumatic) be developed to transfer the semisolid products and debris under all normal arctic environmental conditions. Concurrent test and development of techniques for herding the oil on marine waters such as sweeping with nets should be conducted.

3) The inaccessibility of most shorelines of Alaska indicates that low-cost, durable and extremely portable storage containers will be required for temporary storage with capacities up to 200 barrels. It is therefore recommended that the design of commercial above-ground swimming pools (rigid frame with a flexible liner) be adapted for use in areas free of permafrost. The greatest problem expected in the development is provision of a tightly-sealed lid capable of handling snow loads without overflowing the contents below. An inflatable plastic pillow floating on the oil appears to be the best approach.

3.2 RECOMMENDATIONS FOR TEST AND DEVELOPMENT IN BURNING AND INCINERATION

1) Incinerators for use in Alaska must be highly portable and have nearly universal application for the range of spill sizes (up to 50,000 barrels) and types of debris considered in this study. The open-pit type incinerators developed by duPont and Kenting appear to be the most universal in application in that semisolid fluids and debris can be handled. It is recommended that a test and development program be undertaken to reduce the weight of the presently available open-pit units and adapt all auxiliary systems for arctic use.

2) Homemade incinerators such as 55-gallon drums with small gas burners can handle small spills (up to $\sim$100 barrels) and debris. The portability of these units may be required for handling small spills in

remote areas. Small incinerators of this type should be constructed, mounted on skids, and provided at all Coast Guard bases and stations in Alaska.

3) In many arctic oil spills, the product is not expected to be transferrable due to high viscosity. It is recommended that development of incinerators that can be emplaced and function directly in the spill be undertaken to avoid transfer of the product. Controlled burning by incineration may be necessary for both onshore and marine spills. A barge-mounted unit would be feasible for most marine spills in Alaska. Units for onshore spills would have to be air transportable by HC-130 aircraft.

4) Smoke-free incineration is desirable from the standpoints of air pollution and esthetics. It is recommended that conventional methods for eliminating the emission of smoke such as high temperature burners or water injection be laboratory tested under a range of arctic oil spill conditions. Systems which appear promising should be developed for use in the arctic either by adaptation to conventional incinerators or production of new types of incinerators.

5) Gas turbine type burners such as the NAO or John Zink offer promise for very high rate disposal of liquids with compact units. Long range development is recommended to alter the physical or chemical properties of spilled products to produce compatability in handling with this type of burner.

3.3 RECOMMENDATIONS FOR TEST AND DEVELOPMENT OF IN-SITU BURNING TECHNIQUES

1) Insufficient data is available regarding the properties of spilled petroleum products germane to in-situ incineration. It is recommended that in-situ burning experiments be initiated both in the laboratory and in Alaska over the full-range of petroleum product types and mixtures expected. The in-situ burning tests should be conducted in conjunction with the oil behavior tests recommended in Section 3.1.

2) Techniques for remote ignition of slicks should be developed for the cases of completely inaccessible spills or gasoline spills. It is recommended that remote incendiary techniques available in Alaska from the military and other federal agencies be reviewed and incorporated into Coast Guard capability either by adaptation or cooperative agreement. The Bureau of Land Management, Division of Fire Control, has developed incendiary techniques for starting backfires from helicopters which may have application at remote oil spill sites. The military may have napalm bombs available in Alaska to promote burning.

3) In-situ burning of spills would almost certainly be the preferred method of disposal if the process were smoke-free. It is recommended that research be undertaken to determine the feasibility of water-spray systems for use in conjunction with in-situ burning of a range of arctic spills.

4.0 DISCUSSION

4.1 PROPERTIES OF PETROLEUM PRODUCTS

The types of product spills considered in this study include: crude oil, distillate fuel oil, residual fuel oil and gasoline. The only properties or characteristics of these products of significance for evaluation of equipment and techniques for storage and disposal are the engineering properties at the time the spill is recovered and subsequently handled. The physical and chemical properties of refined products are fairly well-known in the pure state down to the temperatures encountered in the Arctic (see Appendix A). However, little information is available regarding the behavior when mixed or emulsified with seawater, snow or ice. Viscosity of the mixture is an extremely important parameter from a standpoint of handling in the arctic and sub-arctic environment. Emulsification, weathering and cold temperatures all tend to increase the viscosity. Transfer of the product by conventional pumping systems becomes virtually impossible as the product approaches the pour point. The presence of large amounts of debris such as snow or ice produces mixtures that cannot be pumped. Pumping is the universal method of efficiently transferring large quantities of liquid petroleum products over virtually any distance. Logistic problems essentially preclude the possibility of lowering the viscosity of the mixture by either chemical alteration or heating, particularly in the case of large spills. The information that could be found regarding the pertinent properties of petroleum products in the arctic environment appear in Appendix A.

Large oil spills in Alaska will most likely be crude oil because of the lack of industrial development and population, the vast potential for crude oil production, and the fact that the crude oil will be refined outside of the state. The properties of the crude oils from Cook Inlet and one or two wells at Prudhoe Bay are known and appear in Appendix A.

Crude oils from numerous other potential fields around the state and pools within the fields such as the Lisburne Pool near Prudhoe Bay are unknown because the oil has never been removed from the reservoirs.

4.2 HANDLING CONSTRAINTS

4.2.1 Environmental

In the event of a significant oil spill in the Alaskan environment, the existing weather conditions will determine in a short period of time the state of the oil i.e., whether it will remain fluid, mix with snow and ice or turn to a semisolid. If conditions are present which cause the oil spill to increase in viscosity to the point of becoming semisolid, subsequent storage and disposal problems will be more complicated requiring different techniques than if the oil were to remain in a fluid state.

Oil spills will likely be in isolated areas where oil spill response may take more than one day before handling of the spilled product begins. In such cases, information or deductions regarding how fast the oil changes properties may help determine the most effective type of equipment for handling and disposing of the oil. The factors important in this respect are the properties of the oil, nature of the surface on which the oil spill takes place, and the meteorological conditions. The pour point of Prudhoe Bay crude is around 15°F (-9.4°C) and that of some Cook Inlet crude is even higher (>30°F). Such high pour points indicate that the oil could solidify if temperature conditions were as low or lower than the pour points. Such temperature conditions are frequently met during the Alaskan winters.

Petroleum products spilled on water surfaces would normally not solidify except under special meteorological conditions unless the pour point is above $\sim$30°F. Most spills on snow, ice, and frozen tundra would be susceptible to being solidified. A number of meteorological factors would be involved in determining whether an oil spill would remain a liquid or solidify. Some of these factors would be temperature, wind, net long-wave radiation, solar radiation and turbulence. A schematic of a simplified heat loss (gain) diagram for an oil layer on the surface is shown in Figure 4-1. The oil layer loses or gains heat by various heat fluxes.

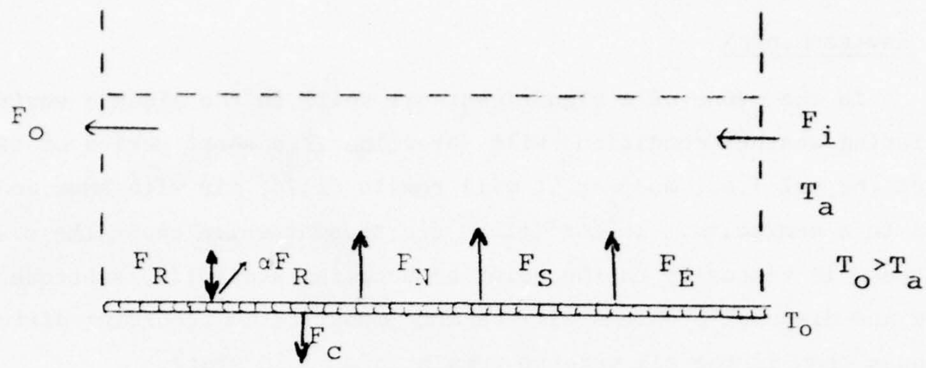

FIGURE 4-1 . SIMPLIFIED HEAT LOSS (GAIN) DIAGRAM FOR AN OIL SPILL LAYER

which include,

F_N - net long-wave radiation

$\Delta F(F_o - F_i)$ - Horizontal advection of sensible heat

F_R - Solar radiation

F_S - Sensible heat

F_E - Evaporation

F_c - Heat conduction

The only major energy flux which could contribute to further heating of an oil spill would be the incoming solar short-wave radiation (F_R). However, part of this energy is reflected from the surface (αF_R). Even so, this heat source would only be available during the period of light and would be absent during most of the winter at these high latitudes.

To illustrate how fast an oil spill could cool down in the adverse climate of Alaska, the heat loss from a hypothetical oil spill is roughly calculated by just considering the net long-wave radiation.

The conditions and assumptions for this calculation are;

Assumptions	Conditions
1. Winter darkness	1. Density of oil $\rho_o = 0.88$ g/cm^3
2. Clear skies	2. Specific heat of oil $C_o = 0.6$ cal/g°C
3. Low water vapor	3. Thermal diffusivity of oil $k = 0.0007$ cm^2/sec
4. No wind	4. Emissivity of oil $\varepsilon = 0.95$
5. Air temperature $T_a = -10$°C	5. Pour point of oil -9.4°C
6. Initial temperature of oil $T_o = 38$°C(100°F)	
7. Net long-wave radiation leaving the oil surface $R_N \sim 0.388$ Langley min^{-1}.	

The calculation is performed by using an expression for determining nighttime surface temperatures by the net long-wave radiation,(1)

$$T-T_o = -\frac{R_o}{f}\left[\frac{2f}{\rho_o C_o k_o^{\frac{1}{2}}}\left(\frac{t}{\pi}\right)^{\frac{1}{2}} - \left(\frac{ft^{\frac{1}{2}}}{\rho_o C_o k_o^{\frac{1}{2}}}\right)^2 + \frac{4}{3\pi^{\frac{1}{2}}}\left(\frac{ft^{\frac{1}{2}}}{\rho_o C_o k_o^{\frac{1}{2}}}\right)^3 - \cdot\cdot\right]$$

where R_o is the initial value of R_N and T_o that of T, at time $(t) = 0$.

The parameter $f = \frac{dR}{dT}$ is a variable that expresses R_N as a function of temperature and was taken as;

$$f = 0.005 \text{ cal cm}^{-2} \text{ min}^{-1} \text{ deg.}^{-1}.$$

which corresponds to the formation of a fairly large temperature inversion.

The results of the calculation are shown in Table 4-1 . These rough estimates indicate that the pour point of the oil would be reached between 3 and 6 hours even without the additional cooling effects of advection, sensible heat flux, evaporation and conduction of heat to underlying surfaces.

TABLE 4-1 . COOLING OF OIL SPILLED LAYER BY NET LONG-WAVE RADIATION

	3 hrs	6 hrs	12 hrs
$T-T_o$	-33°C	-56°C	-100°C

This rough calculation indicates that oil spilled in the Alaskan environment especially in winter is subject to fairly rapid heat loss. However, the problem needs to be looked at in greater detail since this calculation is just a rough approximation. A more rigorous solution could be provided by considering a more complete model of the cooling process.

4.2.2 Debris

Different types of waterborne debris may be present in several locations along the Alaskan coast in quantities that may be major impediments to the recovery and storage of oil spills. In some cases, the extent of the debris may not be a significant factor at all but where debris is present in quantity, spill-recovery efforts will be more difficult, time-consuming, and costly than in locations with little debris concentration.

Since Alaska has a rich biota population it will be necessary to consider birds, marine mammals, and fish as potential debris in the case of an oil spill and the recovery-storage operation.

An extensive study on waterborne debris for the contiguous zone of the continental United States and Hawaii has just been completed by Hancock, et al,(2) for the Coast Guard. We have relied on this work for defining categories and sources of debris and have modified the information where necessary in order to take into consideration the environment and geographical setting of Alaska.

The conditions and assumptions for this calculation are;

Assumptions

1. Winter darkness
2. Clear skies
3. Low water vapor
4. No wind
5. Air temperature $T_a = -10°C$
6. Initial temperature of oil $T_o = 38°C (100°F)$
7. Net long-wave radiation leaving the oil surface $R_N \sim 0.388$ Langley min^{-1}.

Conditions

1. Density of oil $\rho_o = 0.88\ g/cm^3$
2. Specific heat of oil $C_o = 0.6\ cal/g°C$
3. Thermal diffusivity of oil $k = 0.0007\ cm^2/sec$
4. Emissivity of oil $\varepsilon = 0.95$
5. Pour point of oil $-9.4°C$

The calculation is performed by using an expression for determining nighttime surface temperatures by the net long-wave radiation,(1)

$$T-T_o = -\frac{R_o}{f}\left[\frac{2f}{\rho_o C_o k_o^{1/2}}\left(\frac{t}{\pi}\right)^{1/2} - \left(\frac{ft^{1/2}}{\rho_o C_o k_o^{1/2}}\right)^2 + \frac{4}{3\pi^{1/2}}\left(\frac{ft^{1/2}}{\rho_o C_o k_o^{1/2}}\right)^3 - \cdots\right]$$

where R_o is the initial value of R_N and T_o that of T, at time (t) = 0.

The parameter $f = \frac{dR}{dT}$ is a variable that expresses R_N as a function of temperature and was taken as;

$$f = 0.005\ cal\ cm^{-2}\ min^{-1}\ deg.^{-1}.$$

which corresponds to the formation of a fairly large temperature inversion.

Categories of Waterborne Debris - Hancock, et al,[2] defined eight categories of waterborne debris that was found in coastal and offshore waters of the continental United States and Hawaii. We expect that waterborne debris in Alaskan waters may be similarly categorized. The categories are:

- Category I - General Wood Items
  Examples: Boards, Branches, Planks, Tree Stumps
- Category II - Nonrigid Shapes
  Examples: Birds, Fish, Innertubes, Tires, Seals
- Category III - Rigid Shapes
  Examples: Kelp Seeds, Plastic, Toys, Lobster pots, Boat pieces
- Category IV - Flexible sheets
  Examples: Canvas, paper, plastic bags, rags, leather, rubber
- Category V - Rigid Sheets
  Examples: Plastic, plywood, bark, hatch covers
- Category VI - Amorphous Material
  Examples: Algae, grease, wax, peatmoss, tars
- Category VII - Filamentous pieces
  Examples: Fishing line, kelp, nets, rope, seaweed
- Category VIII - Special Cases
  Examples: Bottles, oil drums, paper cups, cartons

Sources of Debris - The relative quantity of debris found in a given location will vary from location to location depending on several factors such as population density, shore front development, local storms, tides, logging activities and density of biota. For a given location, the concentration of debris is affected by winds, waves, currents, and configurations of shoreline. All of these factors are briefly discussed below.

Man Related Sources

Metropolitan Areas

In general, the denser the population in the near-shore area, the greater the amount of debris input to the water in that location. This debris may come from sewage, storm drains, dumping, and industrial plants.

Commercial Logging

Commercial logging activities may create debris by 1) leftover logging material onshore being washed out to coastal waters during heavy rainfall and spring thaws, and 2) transportation of logs by barges and rafting.

Waterfront Construction

Waterfront construction and shipbuilding activities may contribute a variety of wooden debris, plastic, and litter to the water.

Derelict Structures and Vessels

In some locations abandoned and decaying waterfront structures and vessels would contribute a variety of wooden debris to the shore waters.

Ships

Cargo, fishing and recreational vessels contribute debris to offshore areas. Debris from this source is generally litter but occasionally fishing line, nets, floats, and rope are discarded or lost in the water.

Shipwrecks

Shipwrecks can provide a dense local source of debris in a spill. Since the source of spilled oil in some spill situations is a sinking or sunken tanker, the onboard debris will enter the water with the oil. Ships carrying large amounts of small buoyant items can present a severe situation in which a great deal of small floating material could become mixed in the oil.

Old grounded shipwrecks may be minor but persistent sources of debris in certain locations.

Industry

One of the major industries of Alaska is fishing and processing of fish. During the fishing season, in certain locations, fish canneries may discharge large amounts of fish remains and other debris to the coastal waters.

Biota-Related

Birds

Several regions of Alaska are used by a variety of birds for nesting habitat, breeding grounds and migration routes. Birds particularly marine birds are a definite potential debris problem in relation to oil spills. In fact, it may be the biggest potential oil debris problem in Alaska, since regions for potential oil development overlap waterfowl and shorebird breeding habitats and migratory routes[3].

Marine Mammals

Various marine mammals such as seals, walrus, whales, sea lions, porpoise, sea otters are found in Alaska coastal waters. Some seal and sea lion rookeries are located near potential oil spill sites. Oil may be toxic to seals and sea otters and they should be considered as possible debris in an oil spill.

Fish

Finfish such as salmon, halibut and herring and shellfish occupy coastal waters of Alaska. It is possible that salmon and herring when near the surface could be killed by spilled oil and thus become debris. Shellfish should be a minor problem since they are usually located in deeper waters.

Kelp

Kelp beds are plentiful in the coastal waters of Alaska during the warmer months of the year. This material can become involved either by the oil spill being transported into the kelp beds or, in the fall and spring, by dead material being driven into the contaminated waters. The potentially large quantities of this marine growth can become a severe debris problem in a spill situation.

Ocean-Related Sources

Ice

Two types of ice exist in the Alaskan waters: 1) winter ice that is formed in one winter's growth and 2) polar (multi-year) ice that is formed over several years. Winter ice can be further categorized into four additional types, sea ice, beach ice, stamukhas and river ice[4].

The properties of ice have a profound effect on the behavior and subsequent fate of oil[5]. It acts on the oil as a barrier, shock absorber, and shelter. Since ice absorbs oil the evaporation efficiency is altered. Oil in contact with ice will change the albedo of the ice, affecting its rate of melt. The melting process allows the oil to sink into the ice surface to be further sheltered.

In an oil spill in Arctic conditions the oil would either spread over the water and ice or migrate under the ice making oil cleanup immensely difficult. Observations[6] indicate that the viscosity of the Prudhoe Bay crude oil allows it to spread easily over ice under summertime arctic conditions. Colder temperatures in the winter, however, will lower the viscosity of the oil sufficiently to cause it to freeze. However, at all times the natural roughness of the ice surface will act to contain the spilled oil.

Multi-year sea ice has a specific gravity of about .85 as compared with .91 for pure, salt-free ice. Specific gravity of Prudhoe Bay crude is around .89. In comparison with the sea ice, crude oil will almost always be more dense, hence if given the opportunity crude oil will flow under multi-year sea ice because of hydrostatic consideration. Campbell and Martin[7] suggest three mechanisms for dispersing oil in multi-year ice from the location of a spill to the surface of the ice. These are lead-matrix pumping, oiled-hummock melting and under-ice transport.

A test program[9] with a small oil spill on an ice field resulted in a greater than normal absorption of solar radiation and a resulting melting of ice. The oil covered ice absorbed about 30% more radiation than the clean ice and initially melted ice at a rate of about 2 cm/day greater than the clean ice.

In a numerical model of air-oil-sea-ice interface problem, Nagel[8] showed that the oil layer changes the latent heat flux and surface albedo causing a net heat gain of 9 K cal/cm^2/year. This increase amounts to 20% of total insolation at the surface and is equivalent to a probable increase in ice ablation of 75% of the original area covered by oil.

Observations[9] indicate that the effect of tides on the movement of oil on water is greatly reduced by the presence of ice which acts as a barrier to the oil. The ice acts as a barrier in two ways: 1) ice booms are capable of partially or totally curtailing the movement of the oil and 2) wind counter to the tidal current not only can slow down the movement of the oil but can effectively entrain it in its own direction.

Tides

Several locations on the Alaska coast have extremely high floodtides. During these periods debris that was stranded on shorelines can be refloated and taken out to offshore waters. This tidal action could transport debris into an oil spill.

Tidal rips or in locations where currents may cause convergence tend to provide lines of stagnant surface water in which lines of debris can collect. The quantity of debris in these lines is usually greater than in open-water areas.

Harbors and bays which do not have a good natural flushing action due to tidal currents, tend to have more debris than other areas with the same relative debris input and good tidal flushing actions.

Currents

Debris, primarily wooden debris, can be transported by ocean currents long distances to eventually end up on a shoreline. This is particularly true on the coastal areas of the Gulf of Alaska. Although it is minor debris in the open ocean, once it lands on a shore the debris may be subject to tides and other currents which concentrate it in local areas.

Debris in near-shore locations tends to be transported by wind and currents to areas of relatively calm water. These areas include the following:[1]

(1) Coves

(2) Bays

(3) Sheltered sides of harbors or estuaries

(4) Underneath and around docks, piers, and ramps

(5) Small islands

(6) Kelp beds.

Tsunamis

The coast of Alaska is subject to periodic tsunamis or severe sea waves generally caused by earthquakes. The extremely high water level accompanying a tsunami can cause large-scale destruction of shorefront structures resulting in a great quantity of waterborne debris.

Weather-Related

Rivers

The greatest amount of debris in rivers is present during and after periods of flooding due to seasonal thawing or severe storms. Flooding causes the rivers to rise above their normal levels and areas normally dry are flooded and washed out resulting in large quantities of debris. The debris enters the rivers and is floated downstream to estuary areas, bays, and the open sea.

Snow

Snowfall or blowing snow has been reported to migrate downward into an oil spill forming an oil/snow crystalline mulch.[9] This mulch was about 80% water by volume. The oil/snow mixture is quite easily handled mechanically but cannot be burned or absorbed. After the mixture is saturated (a few hours) additional falling or blowing snow covers the oil making visual detection impossible.

A slush avalanche was responsible for an oil spill from a storage tank farm along the coast of Deception Bay in Canada[5] and may be a potential mechanism for causing oil spills from storage facilities near sloping terrain in Alaska. In addition, it may be a means of causing snow and ice debris to be transported into a spill.

Slush avalanches have been reported in Alaska[10] as occurring in the spring following intensive thawing. The major factors causing slush avalanches are:

1) The presence of a snow-filled gully which may contain a frozen stream.

2) The production of more meltwater than can drain through snow,

3) And a gentle terrain slope usually not greater than 15°.

When the snow surface, wind and temperature conditions are ideal surface snowballs or snowrollers may be transported by the wind over considerable distances. This may be another mechanism for snow debris to get into an oil spill on a snow surface.

High Velocity Winds

Wind is one of the principal modes of spreading and transporting oil on water and ice. High velocity winds not only can transport snow debris into oil but also other types of debris such as sand and general litter.

At the Deception Bay oil spill high velocity winds were partly responsible for the slush avalanche that caused the oil spill. After the oil was on the ice,high winds were reported to have resuspended oil droplets from the ice and transported them considerable distances, even as far as the other side of the bay. Small spherical potholes were created and filled with oil and wide irregular water ponds were covered with a thin film of oil[5].

Storm Surges

Along the Alaskan coastal areas especially in the lower coastal areas of western Alaska storm surges may occasionally inundate the coastal areas causing widespread damage to biota, shoreline features and structures. The resulting damage produces a variety of debris some of which may eventually reach the open sea or be deposited on the shoreline.

Shore characteristics - The configuration and composition of the shoreline is also important in relation to the debris problem. The configuration of the coastline in a local area will determine whether the coast is favorable for collecting debris under most wind, tide and current conditions.

The composition of the shoreline, i.e. whether it consists of large boulders, gravel, sand, mud, marshes, ice, cliffs, is an additional factor which will have to be considered in the disposal and storage of an oil spill.

Observations on the effects of oil on beaches and shorelines have been made at Chedabucto Bay[11] and San Francisco Bay[12]. The following observations of Barber concerning the spill at Chedabucto Bay are of interest:

> "Early in our observations from the air it seemed, too, that there was generally less evidence of oil on sand and gravel beaches than on adjacent rocky foreshores; however, ground examination would frequently show that there was considerable oil in the beach material, frequently close to the high and storm tidelines. . . . . It was clear that a reduction in the amount of oil was also taking place on rocky foreshores. This seemed to take two forms: (1) a gradual reduction in the amount of oil contained by the roughness of the rock (of any dimension) and (2) a gradual reduction in the amount of oil on the rocks throughout the range of the tide, but greater at the lower tide range.
>
> The existence of sand in oiled areas had become of special significance for our observations indicated, (1) that sand with wave and water action effectively moved (abraded) oil from rocky shores, (2) that sand mixed with oil effectively modified the character of this oil (frequently oil was picked up so mixed with sand that it would not adhere to or stain the hand) and (3) that it was possible to stabilize large areas of oil (in sheltered regions) by mixing (with) quantities of fine sand."

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4.3 ALTERNATIVES FOR STORING RECOVERED OIL AND DEBRIS

Two distinct types of storage requirements can arise in a normal oil spill situation: 1) the need for immediate storage (or containment) within a period of a few hours to a few days, and 2) temporary secure storage for periods beginning within a few days of the spill and extending up to one year. Extended storage for periods of years is essentially a means of disposal and not considered as a viable alternative in this study. Temporary storage of recovered oil has essentially one purpose in Alaska--to safely retain the product and debris until a means for disposal can be brought to the immediate site. The feasibility of transfer to other locations for disposal is discussed elsewhere in the report and generally felt unfavorable. Storage requirements for spills that are burned in situ are limited to retention of the residue while awaiting ultimate disposal. Experience with storage of spills recovered from the Arctic and sub-Arctic is very limited in Alaska and elsewhere.

The distinction between immediate and temporary storage will not always be clear in all spill situations. The discussion in the remainder of this section is based upon the following general differences:

- Products stored by immediate methods will subsequently be transferred to temporary storage devices or disposed of within approximately one week.
- Immediate storage devices are those used to collect or concentrate products in controlled burning operations.
- Immediate storate devices can be deployed both onshore and offshore while temporary storate is <u>always</u> onshore.
- Immediate storage devices will tend to use natural features or facilities on-site during spill recovery, while temporary storage devices will normally be transported to the site following the spill.

Factors that must be considered in the evaluation of approaches to storage of products recovered from arctic and sub-arctic spills include the following:

- ecological damage--both initial and secondary
- presence of debris (including snow and ice)
- properties of the recovered product
- transportation access and logistics
- cost
- availability
- seasonal environmental effects--climatological and oceanographic
- terrain conditions
- capacity
- time to place in operation
- durability or possibility of reuse
- personnel safety

The factors tabulated above are factored into the evaluation of alternative methods for immediate and temporary storage in the following sub-sections.

Storage of gasoline is not considered feasible because of the potential danger of fire or explosion resulting from field operations and the deleterious effects on personnel caused by contact with the skin and respiratory system in cold environments. Storage alternatives are evaluated in terms of two types of products: (1) solids or semi-solid fluids (including debris) and (2) fluids with viscosities under approximately 100,000 ssu. No distinction is made between crude oil, distillate fuel oil and residual fuel oil from a storage standpoint. It is reasonable to assume that all residual fuel oil and all crudes that have been released for more than one day will be in a semi-solid state when handled in all locations in the Arctic and during an eight to nine months' period in sub-arctic locations.

4.3.1 Immediate Storage

Immediate storage of recovered petroleum products must be weighed against other alternatives such as in situ burning. Marine spills in open water or onshore spills where drainage systems such as rivers are nearby entail the risk of dispersal of the spill to a point that it can never be effectively recovered. Thus, the potential ecological risk of an uncontained spill must be compared to the potentially severe localized ecological damage due to immediate storage, especially in spills where the product cannot be burned in situ. A comprehensive assessment of the potential for ecological damage in the event that the spill is not controlled is beyond the scope of this study. Section 5.0 includes a general summary of local environmental and ecological features at the specific sites selected for evaluation. The primary threat of ecological damage throughout Alaska (particularly in the event of marine spills) is to avifauna. Each storage system evaluated must carefully be considered in light of the ultimate effects on the avifauna.

Approaches or equipment for the immediate storage of oil spills include the following:

- floating containment devices such as booms
- shoreline features such as bays or beaches
- portable containers--both static and towable
- permanent local storage tanks
- natural onshore features such as lakes, snow fields and depressions that can be diked or have other barriers emplaced
- sea ice or shorefast ice
- ships and barges in the local area
- tank trucks in the local area

Immediate storage is effective only if the recovered oil can subsequently be transferred to more secure temporary storage facilities or disposed of directly within less than approximately one week.

Purposely contaminating an onshore lake or beach is advisable only if the potential ecological threat of an uncontrolled spill far outweighs the localized damage from the storage technique.

Immediate containment of all marine spills by booms or similar devices (if available) is recommended for all types of spills except gasoline (for safety reasons) from whence transfer to temporary storage or direct disposal can be accomplished. In the event that oil spill containment booms are not available in time or will not work in a particular environmental setting, the remaining alternatives may be advisable. Each is discussed in terms of potential advantages and disadvantages below.

Intentionally herding or pumping the spill onto beaches or protected areas prevents rapid spread of the spill by wind or currents and permits access to the spill from onshore over an extended period of time. A further advantage is that spills of any size and all types can be handled in this manner. The primary disadvantages are the fact that the product becomes contaminated with any potential debris on the beaches, which complicates subsequent storage and disposal. Also, the fact that a new area is contaminated which may require different approaches to cleanup and restoration is a further disadvantage. Spills driven onto beaches are always subject to refloating at high tides. Driving the oil onto beaches is recommended only for cases where oil skimmers or floating pumps cannot be brought to the scene before the oil dissipates.

Portable floating containers such as the prototype oil salvage containers developed by Uniroyal and Goodyear for the Coast Guard offer an excellent means for immediate storage if the systems required to fill them are available. Several other companies, both foreign and domestic, also manufacture portable oil storage and transportation containers suitable for immediate storage. Examples of these containers are the Dunlop Dracones manufactured in England and the French "Caiman". The portable tanks are towable which can greatly facilitate transfer both at the spill site and subsequently at the secondary transfer point. The primary disadvantage is that the containers are effective only for oil without debris

that can be pumped. Working on and around the tanks in heavy seas and vulnerability to puncture by ships or underwater projections in the shallow coastal waters of Alaska are further disadvantages. Other types of portable containers are discussed in Section 4.3.2. Product specifications appear in Appendix B.

The use of features in nearby sea ice for immediate containment offers many potential advantages, but needs further investigation. Working on moving pack ice is hazardous for personnel, but may be necessary in the event of spills in the ice. The objective of immediate storage in pack ice would be to pump or otherwise transfer the petroleum products onto the surface of the ice where it would be retained by natural or man-made barriers. An alternative approach would be to transfer the product to an open lead and use oil spill booms to contain the spill within the lead. However, the potential of losing the oil under the ice due to surface currents or ice movement favors pumping onto the surface. Shore-fast ice is more stable than pack ice and would be a preferred immediate storage location if a choice were available.

Winter spills in the Bering Sea or Beaufort Sea will be extremely hard to cope with due to cold temperatures, extended darkness and the lack of suitable working platforms. Use of the ice for immediate storage may be the only alternative available for storage for periods of days. Further research is clearly indicated related to the behavior of oil spills in and on the ice and methods to provide barriers to further spread within the ice. The primary disadvantage of using sea ice for immediate storage is the fact that further emulsification may occur during transfer and pumping onto the ice potentially introduces further debris in the form of snow.

The use of natural features onshore and other existing facilities and handling of debris are discussed in Section 4.3.2. Locally available ships or barges afford excellent temporary storage devices but are generally limited to the handling of liquid products and restricted to storage of smaller spills (much less than 1,000 barrels). Disadvantages include

uncertainties in availability which negates long-range planning. The need for secondary cleanup or restoration of the vessels is also a disadvantage. The preferred use of local vessels is in conjunction with portable deck containers rather than direct use of the holds or tanks. Crab fishing vessels and salmon tenders are common throughout the Gulf of Alaska and Bristol Bay area that are capable of holding several thousand barrels of recovered oil in live-holding tanks below deck. Immediate storage in these vessels is advisable only if other satisfactory alternatives are lacking.

4.3.2 Temporary Storage

Significant differences between immediate and temporary storage are the need for long-term stability under a range of seasonal environmental conditions, the requirement for periodic monitoring, and a major need to prevent recontamination by either leaking or sudden failure. Heavy equipment for constructing secondary containment devices such as dikes around storage tanks is almost universally available in the "lower 48" states. The soils are also generally more stable there. Heavy construction equipment will generally not be available locally in Alaska and overland travel to most sites is not feasible during the summer in the Arctic and most sub-arctic regions due to the quagmire existing in the active layer of permafrost. Therefore, the single most important objective of temporary storage is that the containment devices be over-designed to minimize the risk of secondary contamination. Use of multiple smaller containers limits secondary release to only those containers which fail. Therefore, an upper capacity limit of 2,000 barrels is recommended for temporary storage in portable containers.

Factors influencing temporary storage were tabulated in the introduction of Section 4. The ecological damage (both temporary and long-term) that results from either emplacement or the storage devices themselves must be assessed for each specific site and carefully weighed against alternative approaches for storage and disposal. The fact that

all temporary storage is assumed to be onshore opens a new regime to oil pollution that would not have been affected in the case of marine spills. Completely self-contained and sealed devices such as tanks are the soundest approach from an ecological standpoint. However, cost and logistics may favor the use of natural features. The two most universal approaches to temporary storage are: (1) the use of natural onshore features such as lakes or reservoirs created by barriers, and (2) self-contained portable tanks or pools. A ranking of the general utility of these two approaches with respect to the factors influencing temporary storage is tabulated below:

Storage of debris:	(1) use of natural features (2) self-contained devices
Capability to cope with both semisolid and liquids:	(1) use of natural features (2) self-contained devices
Transportation and logistics:	(1) use of natural features (2) self-contained devices
Cost:	(1) use of natural features (2) self-contained devices
Availability:	(1) self-contained devices (2) use of natural features
Seasonal environmental effects:	(1) self-contained devices (2) use of natural features
Terrain conditions:	(1) use of natural features (2) self-contained devices
Capacity:	(1) use of natural features (2) self-contained devices
Time to place in operation:	(1) use of natural features (2) self-contained devices
Durability or possibility of reuse:	(1) self-contained devices (2) use of natural features
Personnel safety:	(1) self-contained devices (2) use of natural features

Self-contained Devices

Two general classes of self-contained portable storage tanks were identified during this study that have widespread application throughout Alaska: (1) pillow tanks or bladder bags, and (2) erectable pools with a rigid frame and flexible liner. Both types are discussed further below. It is assumed that existing storage facilities will be used when available at or readily accessible from the spill site. The use of existing facilities will depend primarily upon the availability of local transportation. Many spill sites will have inadequate local transportation, necessitating the establishment of temporary storage facilities onshore in the immediate spill area. The remainder of the discussion will be limited to those type of installations.

Local terrain will greatly influence the choice of portable storage containers. Permafrost, or permanently frozen ground, is common throughout Alaska. It is continuous in the Arctic and becomes discontinuous or sporatic in sub-arctic regions.[1] The coastal areas of the Gulf of Alaska and Southeast Alaska are free of permafrost. Instabilities in ground footings occur only in locations where the soil contains moisture such as typical tundra. The surface zone affected seasonally by climatological conditions is called the "active layer." The "active layer" thaws during the summer to depths ranging from approximately one foot in the Arctic to several feet in sub-arctic regions.

Structures emplaced on moisture-rich terrain in permafrost regions are highly susceptible to shifting during the thaw cycle of the "active layer." Two general approaches have historically been used to assure sound footings for structures in permafrost regions: (1) destroy the permafrost, and (2) insulate the surface layer to prevent thawing. Neither of these alternatives appears feasible for a temporary oil storage tank because of the emergency nature of oil spill response. A third approach for emplacement of temporary structures is to provide a device capable of floating on the active layer. Pillow tanks or bladder

bags are commonly used for fuel storage in remote regions of Alaska today and the use for temporary storage is recommended for all oil spills in regions of permafrost. Figure 4-2 is an approximate comparison of the capital cost of pillow tanks and steel storage tanks as a function of capacity.

Known operational drawbacks of pillow tanks or bladder bags in Alaska are that bears have ripped the bags open on several occasions[2] and the outer surfaces are subject to puncture and chafing. It is not known whether all presently available bags are designed for snow loading.

Portable pools such as commercial above-ground swimming pools offer the most economical means of storage in portable containers in temperate regions and could be adapted for storage in arctic and subarctic regions. The primary advantages in addition to low cost is portability and the capability to store debris. The use of portable pools with rigid frames and flexible liners is not recommended in areas of permafrost. However, they are the preferred method in other areas due to low cost and transportability if suitable units can be developed for the Alaskan environment. It is recommended that commercial designs be "beefed-up" both in the rigid frame and by using a double heavy-duty liner. A "pillow-type" cover with adequate seals will further be required to provide for runoff of rain and to take snow loads.

A 20-foot diameter pool, four feet high, can safely hold approximately 250 barrels of oil and be hand-carried in sections by one man. Pools have the further advantage of storing oil in either a semi-solid or liquid state and either can readily be loaded into the pools. It is felt that suitable portable pools could be designed which cost under $2,500, or about one-half the cost of pillow tanks.

The utility of portable storage containers for storing oil recovered from spills has an upper capacity limit based on spill size. That limit is felt to be approximately 10,000 barrels because of the cost required to stockpile larger capacities, the logistics of transporting to

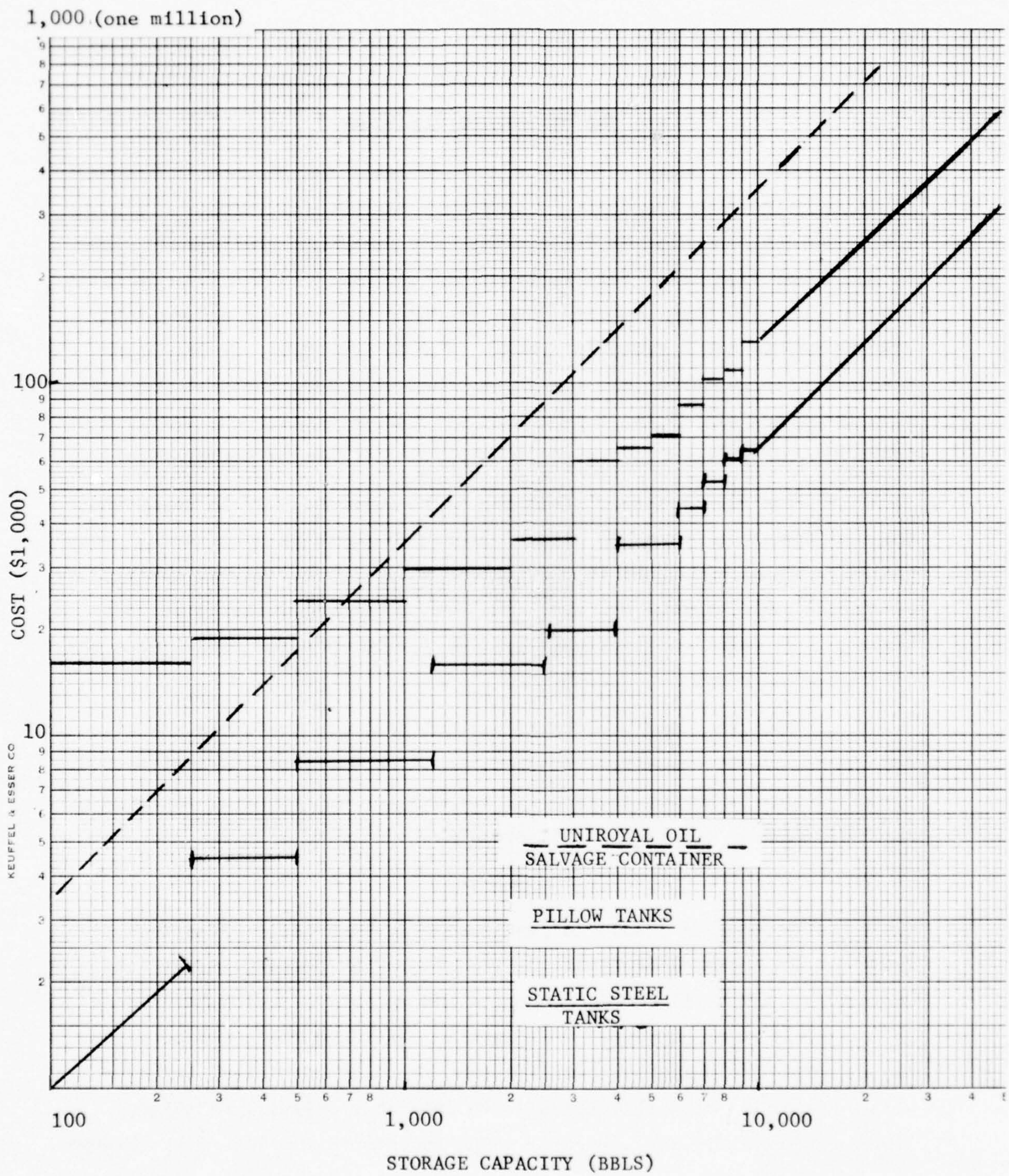

FIGURE 4-2. COMPARATIVE COSTS OF PILLOW TANKS

and erecting at the site and the decreasing probability that the larger spills can be contained for a period sufficient to complete transfer.

Use of Natural Features

Natural onshore features such as lakes and beaches can provide rapid and effective immediate or temporary storage for recovered oil. The petroleum companies at Prudhoe Bay have developed contingency plans to use local thaw lakes for emergency oil storage.(3) The lake is first pumped down with high capacity transfer pumps and the oil subsequently transferred to the surface in summer. The bottom of the deeper lakes remains unfrozen during the winter, so the water is pumped out and replaced with recovered oil during the winter. Secondary containment barriers or dikes are constructed to prevent loss of the oil during spring runoff.

The use of natural features is recommended only in cases that the oil cannot be burned in situ or stored in portable containers. Large spills between 10,000 and 50,000 barrels will severely strain the utility of all portable storage systems. The use of natural features may be necessary to compliment portable systems for these large spills when the oil cannot be burned.

The types and numbers of natural features available are site-dependent and discussed for the specific sites evaluated in Section 5.0. Further study is needed to identify methods to best use a broad range of natural onshore features for oil storage.

Debris

Storage of debris is problematic in most spill situations because debris cannot effectively be transferred by pumping. Therefore, containers must be lightweight, rugged and capable of being handled by both men and light equipment. It is also desirable that they be combustible. The most suitable container that could be identified for handling small quantities of light debris is the portable shipping containers developed primarily for air cargo. The containers consist of knock-down

waxed cardboard sides and a lid mounted on a standard pallet. The dimensions are approximately 4' x 4' x 4'. The major materials (wood and cardboard) are combustible which permits incineration without removing the debris. A suitable plastic liner would be required to prevent leakage of liquids from the container. A further description is included in Appendix B.

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4.4 BURNING OF COLLECTED OIL AND DEBRIS IN INCINERATION DEVICES

In Section 4.5, in-situ methods for burning spilled oil and debris which do not require collection of the oil and debris are described. These methods included burning the oil in place (with heavy smoke), using water-spray smoke-suppression equipment to reduce smoke formation, and use of smokeless burners. These methods, especially that of merely igniting the oil, are relatively simple and of minimal cost. However, there will be situations where these relatively "simple" methods will not work or will not be feasible. These situations include:

(1) A medium-to-large oil spill (10,000 to 50,000 bbls) followed by a heavy snow (or blowing snow) to create a large amount of mulch-type mixture. Tests have indicated that mulch may contain up to 80 percent snow. The very large oil spill (50,000 bbls), with 80 percent snow added, amounts to 1.34×10^6 ft^3 of snow/oil mulch. This would be a volume of mulch equal to 1 football field piled almost 30 ft high. In reality, the mulch may be only about 6 inches deep, covering an area of about 60 football fields (about 0.1 sq mi). Since this mulch will not sustain combustion itself, it cannot be merely ignited and left to burn. As the area is so large, it may be impractical to drag a burner or burners, as discussed in the next section, over the mulch to "force" burn it. Therefore, in this situation it appears that the best disposal system may be one in which the mulch is collected in large volumes and fed into a high volume burner or incinerator.

(2) An oil spill of any size, if left on ice, snow, or water long enough, may age to the point where the volatiles needed to promote ignition are no longer present. However, it may still be possible to (1) douse the spill with supplemental fuel (gasoline, kerosene, JP 4, etc.) and ignite, or (2) to pull a mobile burner device over the oil. However, neither of these methods may be practical for large oil spills because of logistics of auxiliary fuel supply. The best disposal system may be one in which the oil is collected (either pumped or shoveled) and fed into a high volume incinerator or burner.

(3) An oil spill (whether in a liquid, semi-liquid, or solid form) that is in an area where an open, uncontrolled fire would pose serious danger to housing, equipment, the landscape such as forest or tundra, or personnel, must necessarily be collected. For instance, an oil spill that pools about a break in the pipeline may cause fire damage to the pipeline if ignited. Of course, if liquid oil could be channeled to a remote area and burned safely, then collecting the oil may yet be avoided.

(4) In general, any large spill that includes mixtures of oil, snow, or ice, mulch, and debris, especially with the requirement for clean burning, will necessitate collecting the oil and burning it in a high capacity burner or incinerator. For the very small oil spills, (up to 100 barrels) homemade incinerators, such as 55 gallon drums, would probably be sufficient for burning all the oil and debris. The 55-gallon drum incinerator could be constructed by merely attaching a gas-fired bunsen or meker type burner to the inside surface of the drum firing into the oil or debris. Combustion air vents would be punched in the drum above the maximum oil level (say, halfway up the drum). If the oil viscosity is low enough and if the oil can be pooled, it may be possible to pump the oil to the incinerator. If the oil viscosity is too high for pumping,or if the oil has spread out over the land, ice, or snow surface, men with shovels and wheelbarrows would be required to load the incinerators.

The remainder of this section will discuss the various burners and incinerations capable of handling the larger size oil spills (100 to 50,000 barrels). Both conventional burners and incinerators requiring additional design and development work will be covered.

4.4.1 Conventional (Closed Combustion) Incinerators

The types of incinerators used for commercial disposal of garbage, paper, and other solid wastes are somewhat inappropriate for disposal of liquid oil, but they may be marginally appropriate for disposal of oil-soaked waste that is handled as a solid. In general, the size relations

between incinerator volume and burning rates, as developed for solid wastes, are unduly conservative for burning of oil. For example, Babcock and Wilcox[(1)] indicate that burning of solid waste on grates can be carried out at rates up to about 500,000 Btu/ft^2 hr without excessive carryover of solids out of the unit. The criteria for this size has no relationship with limitations for burning oil, however.

For the burning of oil-soaked waste, certain basic principles for complete combustion of the waste with subsequent low particulate emission from the combustion zone must be considered[(2)]. These principles are as follows.

- Excess air: Air quantities should usually be kept on the order of 50 to 150 percent above the stoichiometric requirements.

- Minimum use of underfire air: This maintains low velocities and through the bed reduces the particulate emission from the incinerator because it keeps small particles out of the gas stream.

- Proper use of overfire air: This provides ample oxygen and turbulence in the combustion space above the fuel bed. The overfire air injected into the system may be as high as 50 percent of the total required.

- Temperature: Temperature in the furnace space should be between 1400 and 1800 F to reduce the rate of smoke formation and odor. Temperatures below 1400 F will produce smoke and allow odor to escape from the incinerator. Above 1800 F there may be sintering or fusing of the ash with the furnace refractories. Excess air is used to control the furnace temperature.

- Sufficient combustion volume: The incinerator should have enough combustion volume to provide sufficient residue time for the burnout of all flying particulate matter. The average heat release per cubic foot of furnace volume should not exceed 25,000 Btu/cu ft-hr.

- Residence time: The residence time in the incinerator should be between 1 and 2 seconds.

- Reasonable loading rates: Low loading rates per square foot of grate surface should be adhered to, even in forced draft incinerators. They should be no more than 60 lb of waste/sq ft/hr.

A previous study[3] performed by Battelle-Columbus for the U.S. Coast Guard investigated types of commercial incinerators typical of those which might be purchased by the U.S. Coast Guard for operation at sea, in harbors, or on land. Figure 4-3 presents a diagram of the incinerator recommended in that study for the burning of liquid wastes, while Figure 4-4 presents a diagram of the incinerator recommended for the burning of solid wastes.

The unit shown in Figure 4-3 is called Model "V" Liqui-Datur and is built by Thermal Research and Engineering Corporation, It consists of a vortex burner, a combustion air blower, a combustion chamber, and an unlined stack. The combustion chamber is lined with a corrosion-resistant refractory suitable for operating temperatures up to 2300 F. The two sizes of this model which are recommended are Model 14V and Model 48V. Model 14V has a maximum heat release rate of 14 million Btu/hr, which is equivalent to a liquid feed rate of 104 gal/hr containing 10 percent by weight of seawater. The weight of the incinerator is about 30,000 lb. One unit this size could burn the oil from a small spill (100 bbls) in 2 days, while 2 of these units could handle the oil from a medium spill (1,000 bbls) in 10 days. With 67 percent water, 290 gal/hr of liquid waste could be burned while maintaining the same heat release rate. The estimated purchase price (1973) of this unit is $52,000 (plus $26,000 installation cost) which includes the basic incinerator plus a packaged gas-fired boiler for steam generation, a steam heated waste oil preheater, and a low energy wet scrubber. The wet scrubber would, of course, be eliminated for Arctic oil spill disposal. Three of the Model 48V incinerators would be used to incinerate 1170 gal/hr of waste oil (with 10 percent seawater), each having a heat release rate of 48 million Btu/hr. These three units would handle a 10,000 barrel oil spill in about 15 days but would probably be inadequate for handling the 50,000 barrel oil spill (would require 15 units operating for 15 days). The estimated purchase price (1973) of each of these units is $77,000, plus about $38,000 for installation, giving a total installed cost of the multiple-unit system of $346,000. The total weight of these three units would be about 156,000 lb.

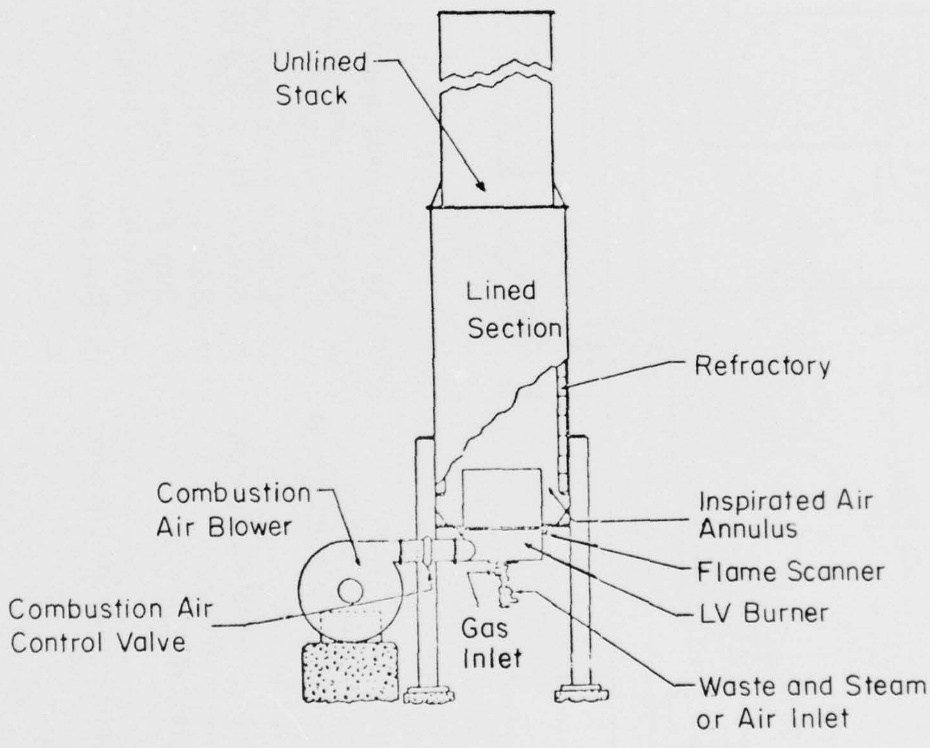
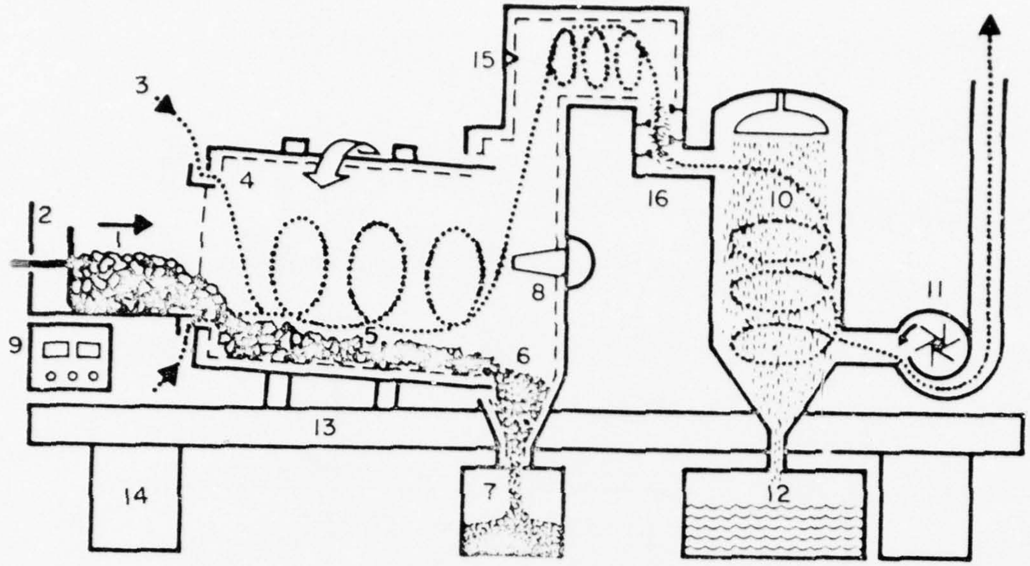


FIGURE 4-3. SCHEMATIC DRAWING OF AN OILY-LIQUID WASTE INCINERATOR

(From the Thermal Research and Engineering Corporation)



1. Waste to Incinerator
2. Auto-Cycle Feeding System: Feed Hopper, Pneumatic Feeder, Slide Gates
3. Combustion Air In
4. Refractory-Lined, Rotating Cylinder
5. Tumble-Burning Action
6. Incombustible Ash
7. Ash Bin
8. Auto-Control Package: Programmed Pilot Burner
9. Self-Compensating Instrumentation Controls
10. Wet-Scrubber Package: Stainless Steel, Corrosion-Free Wet-Scrubber; Gas Quench
11. Exhaust Fan and Stack
12. Recycle Water, Fly-Ash Sludge Collector
13. Support Frame
14. Support Piers
15. Afterburner Chamber
16. Precooler

FIGURE 4-4. SCHEMATIC DRAWING OF A PORTABLE ROTARY KILN INCINERATOR FOR OIL AND SEAWATER CONTAMINATED DEBRIS

(Bartlett-Snow Products)

Another incinerator for burning oily liquid waste is built by the John Zink Company. The basic incineration unit consists of a cylindrical refractory-lined combustion chamber, stack, and a burner with a steam atomizer for waste feed. The purchase price (1973) of such a unit for incinerating 100 gal/hr of liquid waste, containing 10 percent seawater, is $57,000 plus an installation cost of $40,000. The weight of this unit is approximately 30,000 lbs. For burning 1,000 gal/hr of liquid waste, John Zink recommends using 10 of the above units, for an equipment cost (1973) of $411,000, and an erection cost of $200,000. The total weight of these 10 units would be 300,000 lb.

The rotary kiln, shown in Figure 4-4 was recommended by Bartlett-Snow for disposing of solid wastes. In operation, the oily waste is fed into a cylindrical refractory-lined combustion chamber which rotates around an inclined axis. The effluent from the combustion chamber is passed through an afterburner for secondary combustion and then scrubbed with water in a low-energy wet scrubber (this scrubber, of course, would be eliminated for arctic operation). For handling 325 lb/hr of solid waste (containing 50 percent oil), the equipment cost (1973) is $75,000, the installation cost is $105,000, and the total weight is 26,000 lb. For handling 2200 lb/hr of solid waste (with 50 percent oil) the equipment cost (1973) is $180,000, the installation cost is $252,000, and the total weight is 260,000 lb.

The specific results of the U. S. Coast Guard study[3] concerning oil and oil waste incineration systems can be summarized as follows.

(1) Commercial incinerators for burning liquids are presently available in designs burning up to about 400 gal/hr of oil. Units rated up to about 100 gal/hr can be transported with reasonable ease and set up near the spill site. Larger units are not easily transportable.

(2) The cost of oil disposal in a transportable commercial (100 gal/hr) unit (as shown in Table 4-2 is estimated at 47 cents per gallon if the unit is operated only 30 days per year. Since the units are small, 1 unit would be needed for a small spill

TABLE 4-2

SUMMARY OF CONVENTIONAL INCINERATOR COSTS (From Ref. 3)

		Liquid Waste (100 gal/hr)	Solid Waste (325 lb/hr)
Equipment Cost (installed), $		76,000	105,000
Operating Cost[(a)],	cents/gal	47	400
	$/ton		550
Operating Cost[(b)],	cents/gal	16	140
	$/ton		185

(a) At 30 days per year operation

(b) At 300 days per year operation

(100 to 1000 bbls), 12 units would be needed for a medium spill (10,000 bbls), and 60 units would be needed for a large spill (50,000 bbls). Each of these disposal rates assumes complete disposal of the oil in 14 days when burning for 24 hours per day. Since the initial cost of a 100 gal/hr incinerator is over $75,000, the U.S. Coast Guard could invest about $5 million in equipment if this method of disposal is used for a large spill.

(3) Commercial incinerators for solids are available as easily transportable units in sizes up to about 325 lb per hour of solids. If the solids contain 50 percent oil, the feed rate is 21 gal/hr. The cost of oil disposal in one of these units is $185 per ton of solids or about $1.40 per gallon of oil if the incinerator is operated 300 days per year. If it is operated only 30 days per year, the costs increase to $550 per ton of solids or $4 per gallon of contained fuel.

Other incinerators, also of the closed combustion type as discussed above, were analyzed to determine their feasibility for disposing of the various size oil spills. Schwartz, et al(4) reported on the performance of an incinerator designed to handle 150 to 300 lb per hour of waste, simulated by a paper-potato mixture of 5670 Btu/lb heat content (7,960 Btu/hr dry). Figure 4-5 presents a design sketch of this incinerator. This incinerator has a refractory lining, a mechanical ram for continuous feeding, tangential-air firing, and provision for injecting secondary air to the center of the vortex. Air follows a helical path along the wall to the bottom where it contacts the bed of burning refuse. Gaseous combustion products spiral up through the vortex to the furnace at top. Secondary air is admitted to the center of the vortex just above the fuel bed. Auxiliary fuel is included to stabilize combustion when the moisture content of the municipal refuse exceeds 50 percent. The unit is 4 ft in diameter and 7.8 ft high, and the primary air is admitted tangentially through 2 jets at 250 fps. The maximum burning rate is 1,674,000 Btu/hr, or only about 150,000 Btu/hr ft^2 for the 12.5 ft^2 combustion area. For the smallest spill of only 100 barrels, one of these units would be required to operate full time for over 15 days.

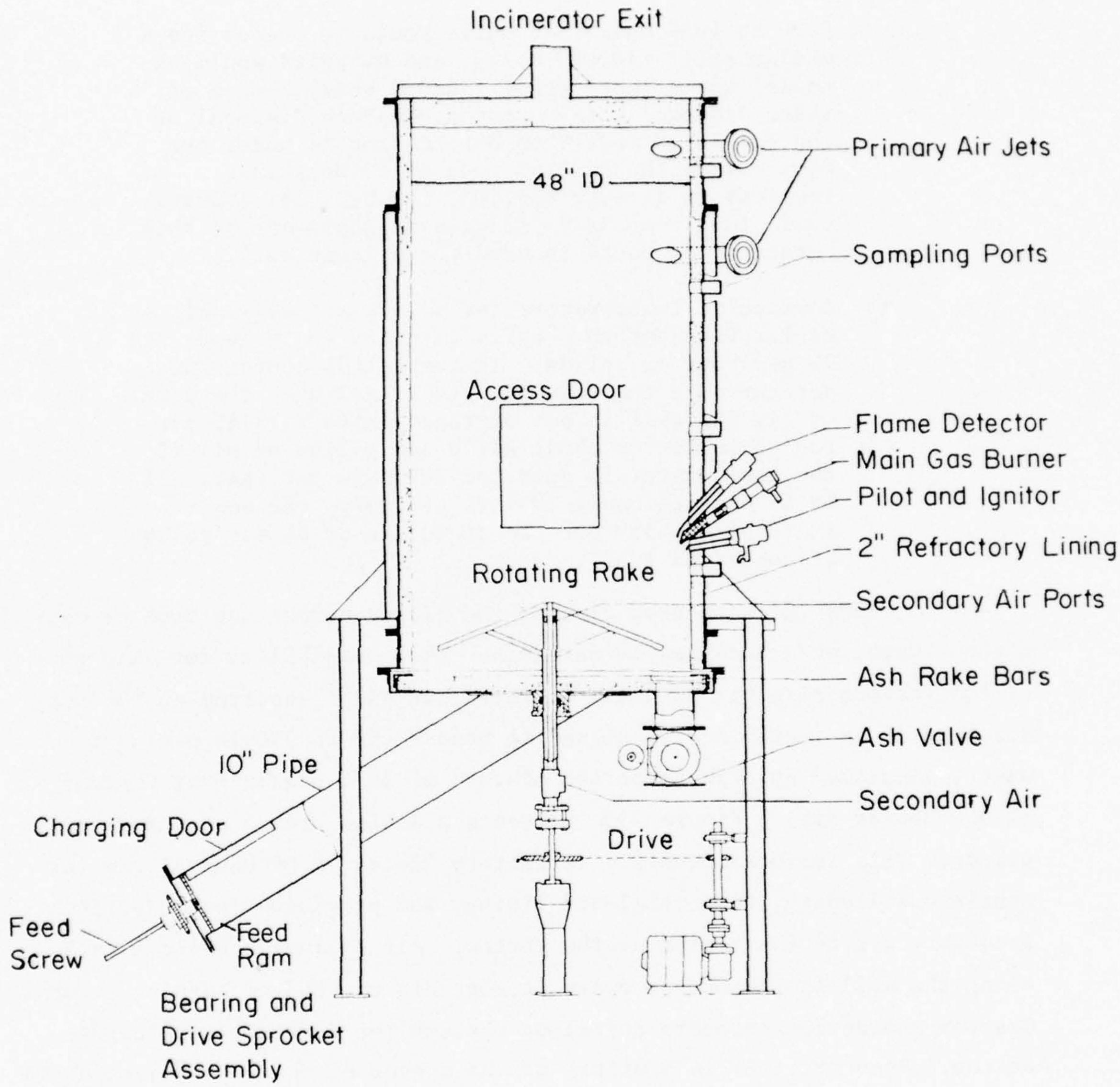


FIGURE 4-5. SCHEMATIC DRAWING OF A CLOSED COMBUSTION, REFRACTORY-LINED VORTEX INCINERATOR

(from Reference 4)

Another larger, commercially available vortex type incinerator, with a minimum of refractory material, is in the H.B.W. incinerator manufactured by Pollution Technical Services Limited of Abingden, England. In this incinerator the waste material is fed into the vortex of a flame and mixed with air. The manufacturer states that a rating of 50,000 Btu/cu ft/hr is obtained without the support of supplementary fuel. Because of the cyclonic flow pattern, refractory walls are not required. An incinerator of this type with a combustion chamber 8 ft in diameter and 10 ft long could dispose of a 100 barrel oil spill in one day and a 1,000 barrel oil spill in only 10 days (although the present design is probably not optimum for burning liquid oil).

Mills and Desman of Energix, Ltd.(5) analyzed the use of three different sizes of cyclone, suspension burning, incinerators having diameters of 1 ft, 2 ft, and 3 ft and lengths of 3 ft, 4 ft, and 6 ft, respectively. All three units were designed to handle solid wastes such as paper, wood shavings, and bark. Figure 4-6 shows a sketch of a typical "Cycloburner". The cycloburner is a horizontal cylinder combustion chamber of refractory chamber forming an annular air space or plenum. Fuel is conveyed into the combustion chamber by way of a materials handling fan or mechanical screw. Combustion air is added through a number of tuyeres around the circumference of the chamber. Both the fuel and air enter tangentially. Combustion can be completed within this primary chamber, or, by regulation of the combustion air, burning can be continued into the second (boiler) chamber. When first starting up, a natural gas burner located in the closed face is used to preheat the chamber for about 15 minutes. The fuel and combustion air are then introduced at a low rate which is increased until the brick reaches a temperature of 900 F. At this temperature combustion is self-sustaining, the gas burner may be turned off, and the feed rate modulated as desired.

The largest unit (3 ft x 6 ft) has a capacity of 2.8×10^7 Btu/hr, or a reaction rate of 8×10^5 Btu/hr ft^3 (with a 2600-2800 F discharge temperature). This incinerator (and the other incinerators mentioned in this section) may require significant design modifications to handle oil and oil-soaked debris. In addition, improved methods for introducing the fuel to the burner must be developed.

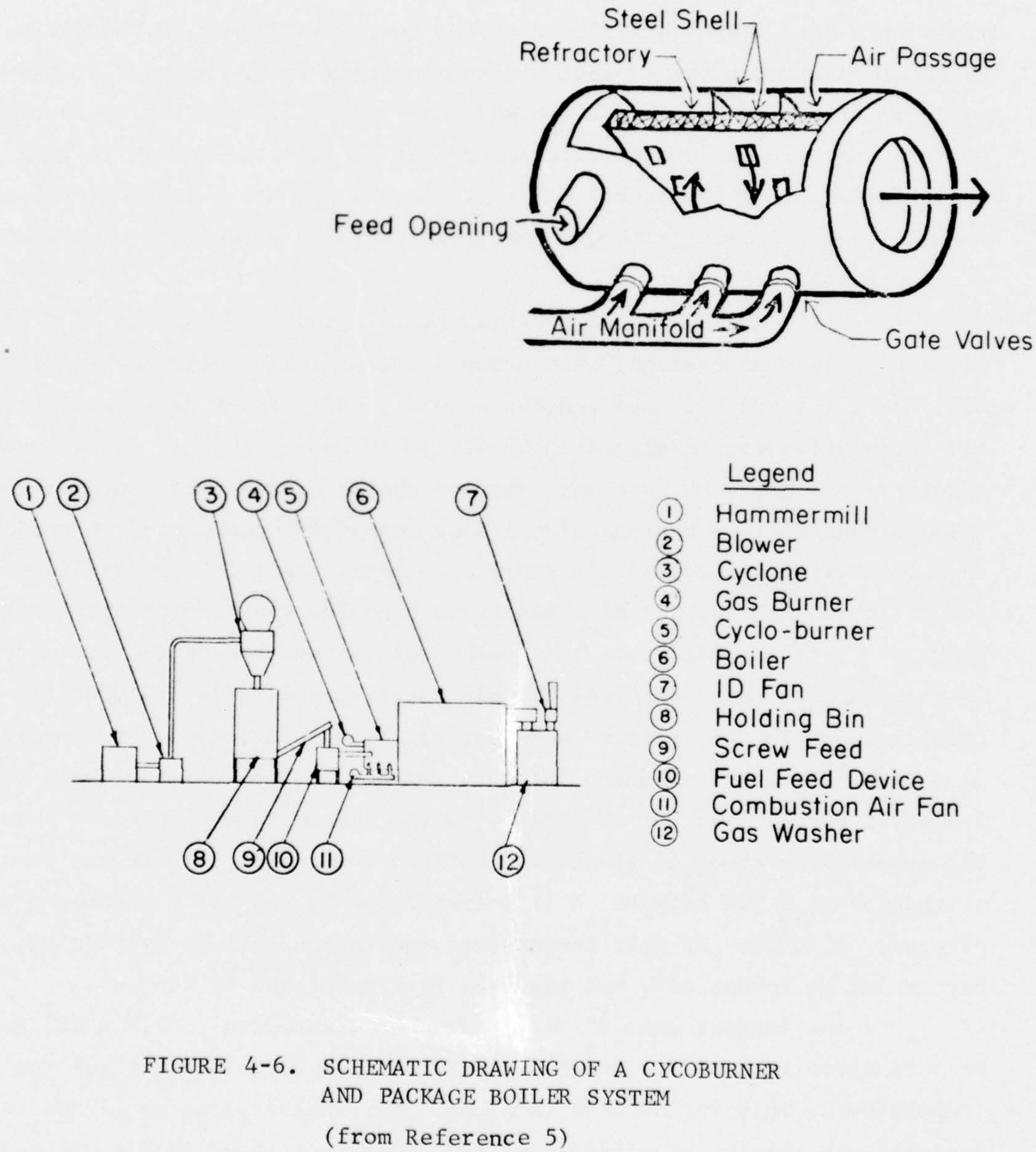


FIGURE 4-6. SCHEMATIC DRAWING OF A CYCOBURNER AND PACKAGE BOILER SYSTEM

(from Reference 5)

Hescheles and Zeid[6] presented a review of three different incinerator systems for disposing of sludge. These incinerator systems included (a) fluidized bed, (b) Herreschoff multiple hearth, and (c) rotary kiln. The information given was rather meager; however, some generalized conclusions were drawn from their work. First, for equal capacity, the fluidized-bed furnace has both high capital cost and high operating cost. Figure 4-7 shows a sketch of a typical fluidized-bed type incinerator. The unit consists of a wind box, a construction plate to support the fluidized bed, a fluidized (sand) bed, a refractory-lined reactor, and a gas outlet. The high pressure air from the wind box flows upward through slots in the horizontal construction plate, enters the sand bed, and agitates the sand. Auxiliaries include a high pressure blower, auxiliary fuel burners, air compressor, etc. At start up, the unit is preheated by the auxiliary burner to approximately 1000 F sand bed temperature. The sludge is then fed through an air atomized whirling nozzle. The moisture in the sludge is liberated as superheated steam. The dry sludge starts to burn in suspension while it drops on the sand bed for final incineration. Sludges that are not self-sustaining require additional heat by the auxiliary burners to maintain furnace temperatures of 1300 to 1500 F. Due to the high capital and operating cost of this type furnace and the large size and weight, it is unlikely that this type incinerator could be used for burning arctic oil spill waste and debris.

Next, the multiple hearth furnace, as shown in Figure 4-8 was shown to have the same high capital costs and operating costs as the fluidized-bed furnace. This furnace, as the name implies, contains a series of circular hearths placed one above the other, enclosed in a refractory-lined steel shell. Waste material fed at the top of the furnace is moved around the hearth by means of a rotating rabble arm to an opening through which it is dropped to the hearth below. The operation is repeated from one hearth to another until it reaches the bottom hearth. The wastes are completely reduced to ashes by the time they reach the bottom hearth from which they are sluiced away. The multiple hearth is designed for exit flue gas temperatures of about 800 F. Auxiliaries include: rabble arm drive, air blower to cool rabble arm, induced draft fan, and auxiliary burners to maintain furnace temperatures. Once again this type furnace is impractical

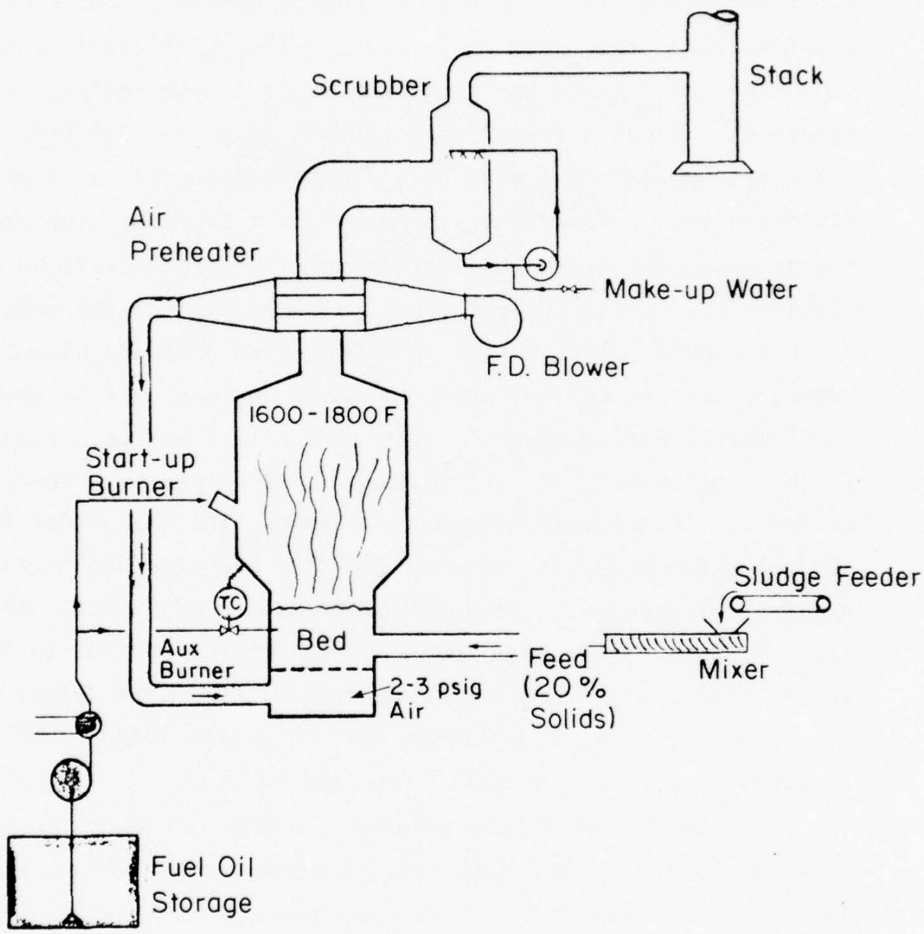


FIGURE 4-7. SCHEMATIC DRAWING OF A SLUDGE-BURNING, FLUIDIZED-BED INCINERATION SYSTEM

(from Reference 6)

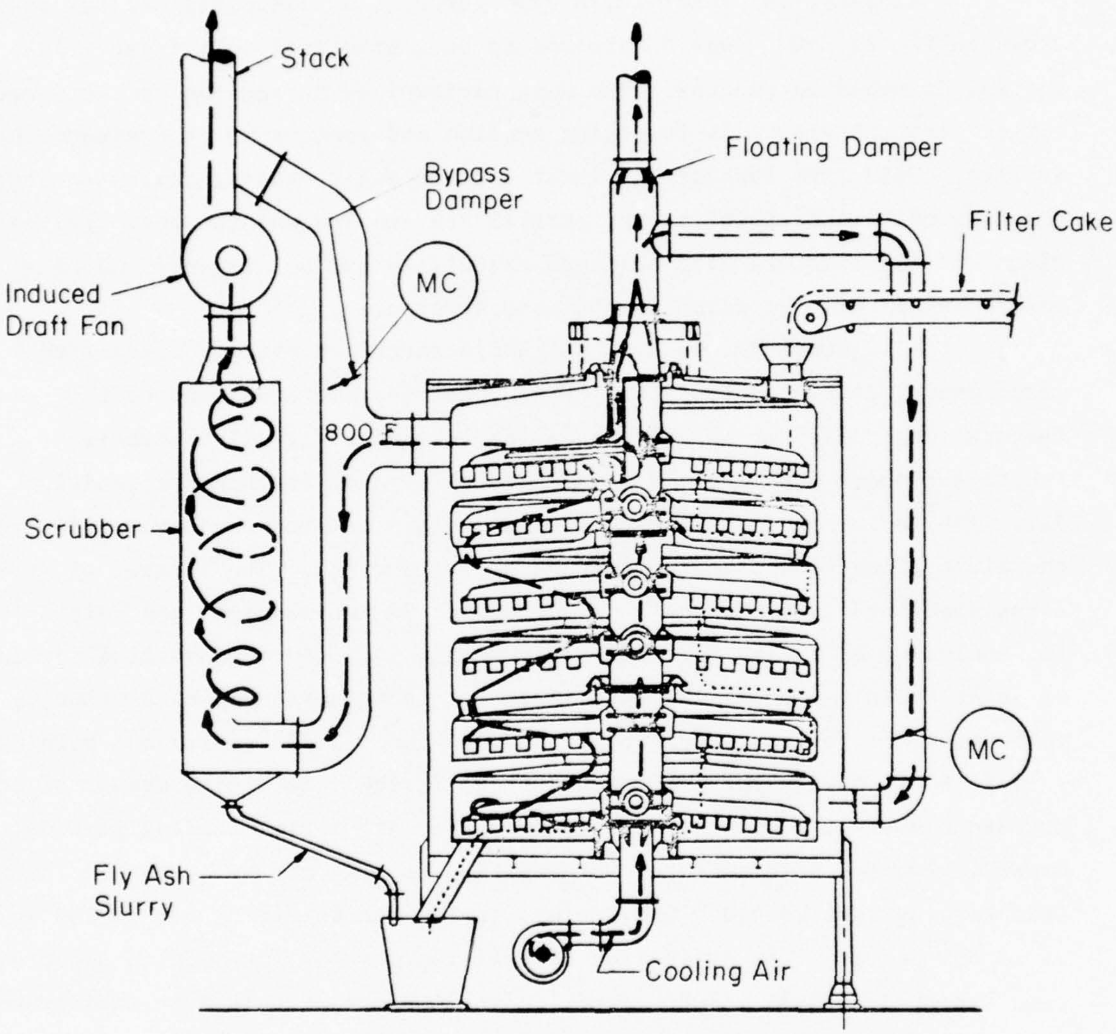


FIGURE 4-8. SCHEMATIC DRAWING OF A MULTIPLE-HEARTH, HERRESHOFF SLUDGE FURNACE

(from Reference 6)

for burning arctic oil spill waste and debris due to the high capital and operating cost and the large size and weight.

Finally, the rotary kiln type furnace, as discussed earlier and shown in Figure 4-4, was determined to be a practical unit if the size and weight could be reduced. The unit reviewed by Herscheles and Zeid was rather large, having a 30 ft drying section and about a 40 ft incinerating section. This type furnace has lower capital and operating costs than the previous units and exhibits high performance and low maintenance. Further discussion of a rotary kiln designed especially for burning oil and oil-soaked debris will be given in the next section.

A lightweight, sheet-metal incinerator for burning classified waste paper, developed at Battelle-Columbus, demonstrates many of the features desirable for an air-transportable burner for oil or debris. Figure 4-9 shows a photograph of the Battelle paper incinerator (Model #1). The incinerator was patterned after a gas turbine combustor, adapting the air cooling technology to burning of solid waste. The largest of three sizes developed is 42 inches in diameter and 84 inches high, and weighs 1000 lb, including a 7.5 hp fan. The basic design is a louvered vertical cylinder of sheet stainless steel having nozzles for introduction of high-velocity combustion air for rapid burning of bound volumes. The continuous burning rate is about 500 lb per hr, equivalent to firing a full file drawer of bound documents every six minutes (air flow is shut off during loading periods). Accordingly, the burning rate over a period of time may be below 500 lb/hr. This burning rate is 4,000,000 Btu/hr, equivalent to firing oil at 250 lb/hr or 18 bbl per day. An evaluation of this incinerator for burning paper has been reported by Hall and Schmitt[(7)]. The largest of this type incinerator that has been built to date is still too small for handling large volumes of oil-soaked wastes. However, a much larger incinerator (with little change in overall proportions) could be built for burning oil-soaked waste at high rates, with very little smoke.

Although this particular design is not appropriate for burning liquid fuel, a large gas-turbine type combustor of similar construction could be built which would easily handle a large spill. This liquid, gas-turbine type burner will be discussed in a later section.

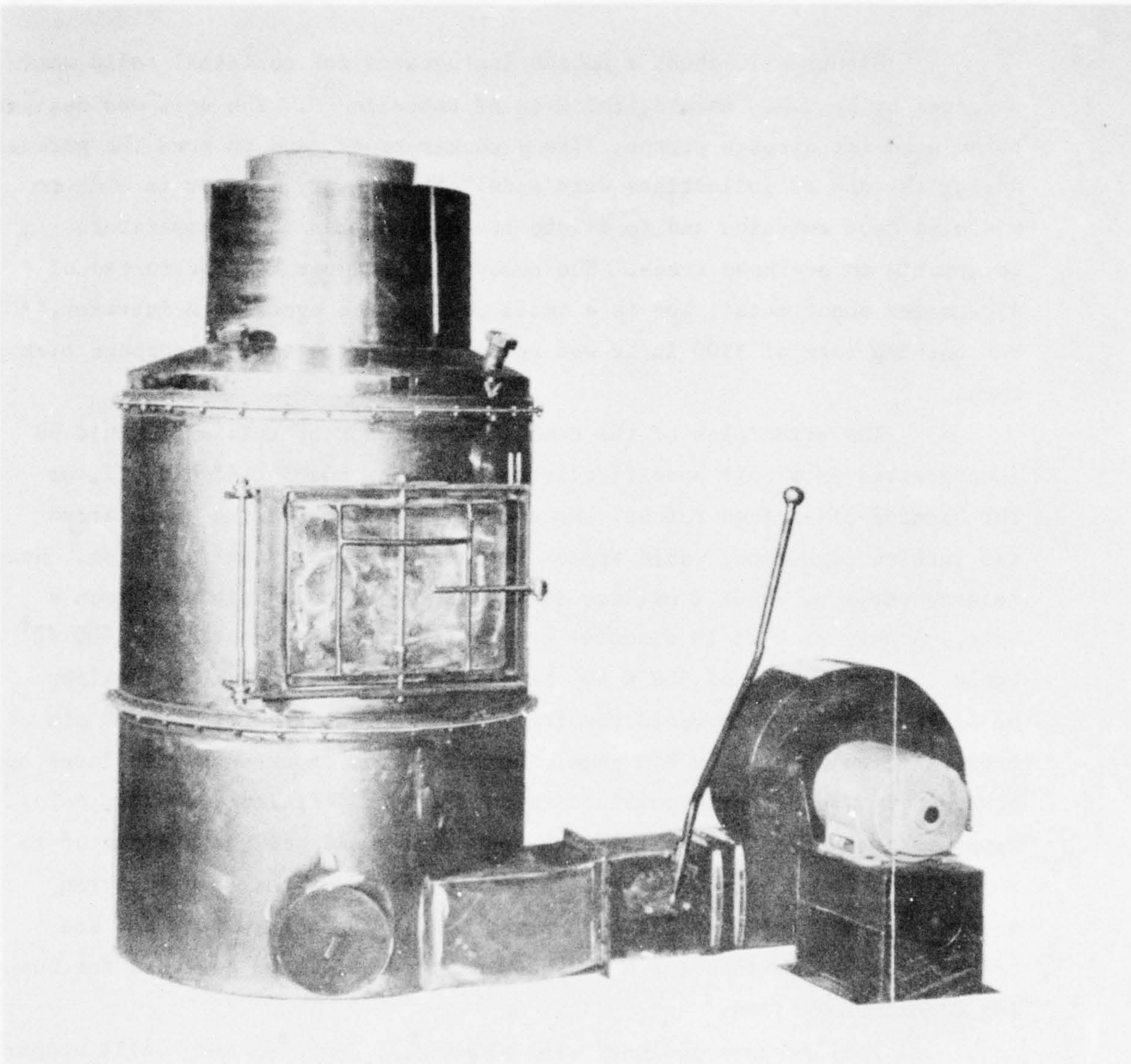


FIGURE 4-9. PHOTOGRAPH OF THE BATTELLE PAPER INCINERATOR (MODEL #1)

Figure 4-10 shows a mobile incinerator for municipal solid waste patented by Engdahl, Hazard, and Hein of Battelle[8]. The unit was designed to be used for garbage pickup, like a packer truck, and to burn the garbage during the day as collections were made. Thus, every attempt is made to minimize dust emission and to dilute the exhaust gas to a temperature acceptable to overhead trees. The combustion chamber is constructed of air-cooled sheet metal, and is a small part of the overall incinerator. The burning rate of 3500 lb/hr was selected to match typical garbage pickup rates.

The principles of the combustion chamber of this unit could be incorporated in a unit specifically designed for burning liquid oil, or for burning oil-soaked refuse. However, a round unit, like an enlarged gas turbine combustor, would appear to be a preferable configuration. Heat release rates of about 1 million Btu/ft^3 hr would be possible in such a unit. A unit of 8 ft in diameter and 12 ft in height, containing 600 ft^3 could burn at a rate of 500 x 10^6 Btu/hr, equivalent to 3770 gal oil/hr or 2154 bbl/day. This would require combustion air flow of 100,000 cfm at a pressure of about 8 in H_2O gage. However, from experience with large open burners, it would appear possible to burn with a deficiency of air, using water spray to prevent smoke. Such operation would produce a flame up to 20 ft long out of the top of the incinerator. The rates of combustion quoted assume burning solids on a grate and oil in suspension, and are considerably lower than for a gas-turbine type combustor designed for burning liquid fuel alone.

Incinerators designed with all-metal, nonrefractory walls appear to be the most attractive units for burning arctic oil waste and debris. When the ceramic lining is eliminated (or minimized) and air jets are used to cool the walls and promote high combustion, the size and weight of conventional incinerators are greatly reduced. If closed type combustion incinerators are to be used for disposing of arctic oil spills, it is recommended that every effort be expended to utilize film-cooled metal walls.

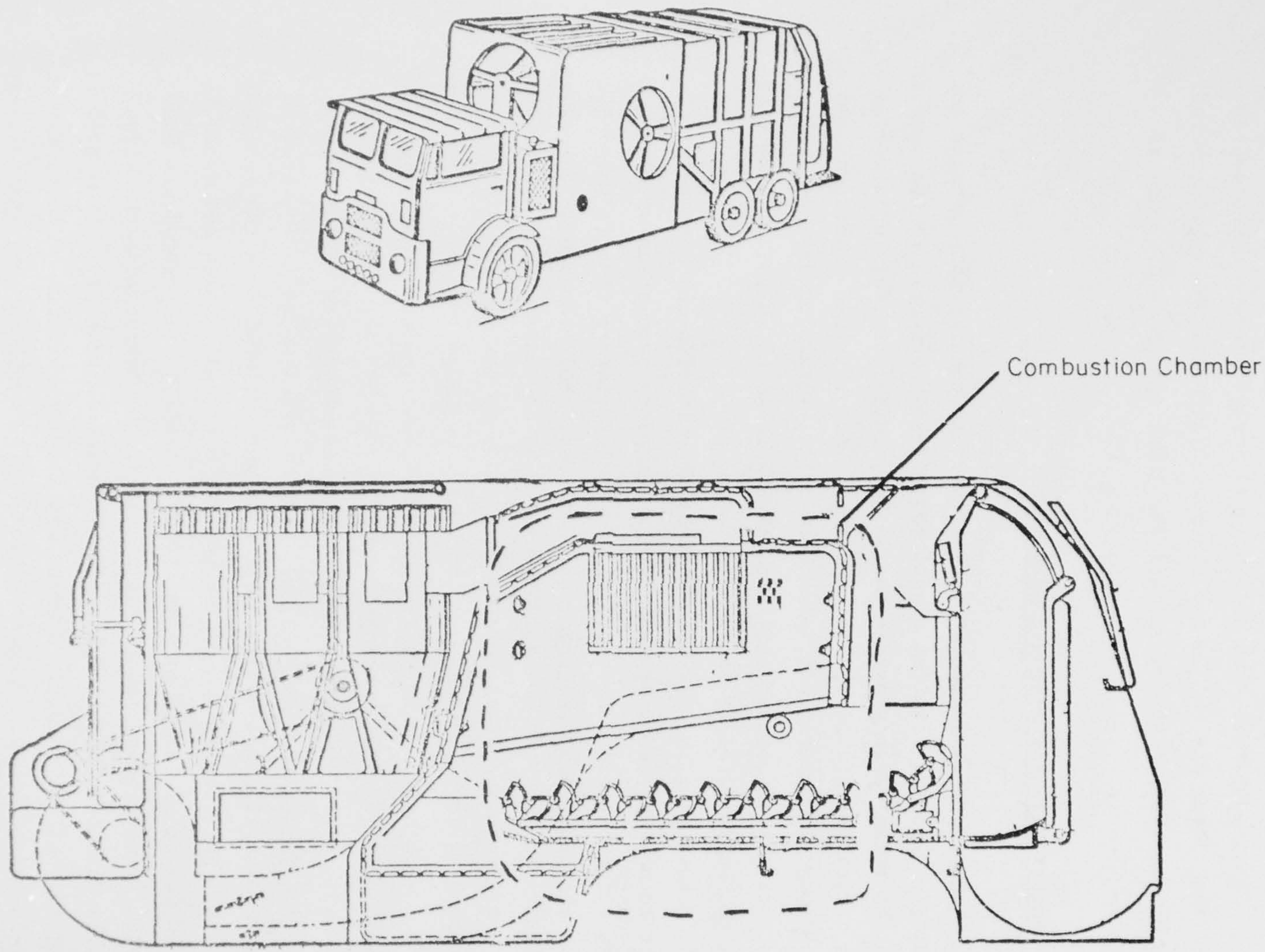


FIGURE 4-10. SCHEMATIC DRAWING OF THE MOBILE INCINERATOR DEVELOPED BY BATTELLE'S COLUMBUS LABORATORIES

It is apparent that conventional incinerators are unacceptable for handling large oil spills and the potential resulting debris; burners or incinerators especially developed for large oil spill disposal are required.

4.4.2 Rotary Kiln for Disposal of Waste

One type of incinerator that exhibits considerable promise for disposing of large quantities of oil and oil-soaked debris is the rotary kiln. The rotary kiln provides the design flexibility for incineration of a wide variety of liquid and solid wastes. Any burnable liquid capable of being atomized by steam, air, or mechanically, through a burner nozzle, can be incinerated concurrently with a wide range of solids. Heavy tars may be fed as solid waste in packs or metal drums.

Rotary kilns provide a maximum of agitation and surface/air contact to achieve complete combustion. Complete combustion of slow-burning refuse is aided by a relatively long residence time in the combustion chamber. Ash discharge is continuous. Roll-through of spherical or cylindrical items is normally prevented by the other solid refuse being incinerated. Since the drive mechanism is outside the kiln, maintenance is low. There are no internal moving parts.

When used for the incineration of waste material with a gross calorific value of less than approximately 5000 Btu/lb, the rotary kiln can be designed to operate with waste material traveling in a direction counterflow to the combustion gases. The material to be incinerated is fed by mechanical conveyors into the kiln and agitated down the inclined barrel, the products of combustion passing over and through the waste in order to dry the incoming material before ignition. The gases are then exhausted from the feed end of the kiln. In the drying zone the kiln barrel is fitted internally with flights which improve drying and prevent balling and pelletizing. In designs for the incineration of waste with a high calorific value, the rotary kiln can be designed such that material within the kiln travels parallel to and in the same direction as the combustion gases. The kiln barrel is usually designed of double shell

construction, the outside shell being forced air-cooled by a separate cooling air fan, although in certain cases air is drawn from the primary air supply. For startup purposes, an oil burner is normally fitted at the ash discharge end of the kiln.

Figure 4-11 shows a diagram of a skid-mounted rotary kiln incinerator developed by the Envirogenics Company for cleaning oil contaminated beach sand and debris (funded by the EPA). A study[9] performed by the Envirogenics Company showed that in-situ burning of oil-soaked beach sand (using torches and flame throwers), even when spiked with kerosene, was quite inadequate. They determined that to obtain adequate burning of the oil from the sand, it was necessary to continuously agitate the oil/sand mixture, and the rotary kiln system provided a method of doing this.

Figure 4-12 shows the basic flow diagram for the rotary kiln of Figure 4-11. In the first chamber, combustion air, recuperatively heated, would be introduced in concurrent flow with the oily sand. The feed would dehydrate, the oil would become evenly distributed on the granules, and partial volatilization and/or pyrolysis of the oil fraction would occur. Before leaving the first chamber, the oil and the sand feed would be carbonized. The granular, carbon-coated sand resulting from this treatment would then be passed into a higher temperature kiln where the gas/solid flow would be countercurrent. Here the carbon would be burned, leaving clean sand. Heat could be extracted from the cleaned sand prior to discharge in a third rotating section.

The unit shown in Figure 4-11 was designed to clean 20,000 lb of sand per hour, carrying with it 5000 lb of oil and 1600 lb of water. Tests have indicated that no auxiliary process heat will be required when the sand contains as little as 6 weight percent oil (dry basis); oil content of waste from a typical excavation operation is about 16 weight percent. The difference in energy level is more than sufficient to dehydrate the sand assuming it contains 6 weight percent moisture. A preliminary cost analysis (1970) has indicated that for the 10 ton/hr design, the total operation and maintenance cost would be $1.28/ton to produce clean sand. For a 60 ton/hr design, the operation and maintenance cost would be 54

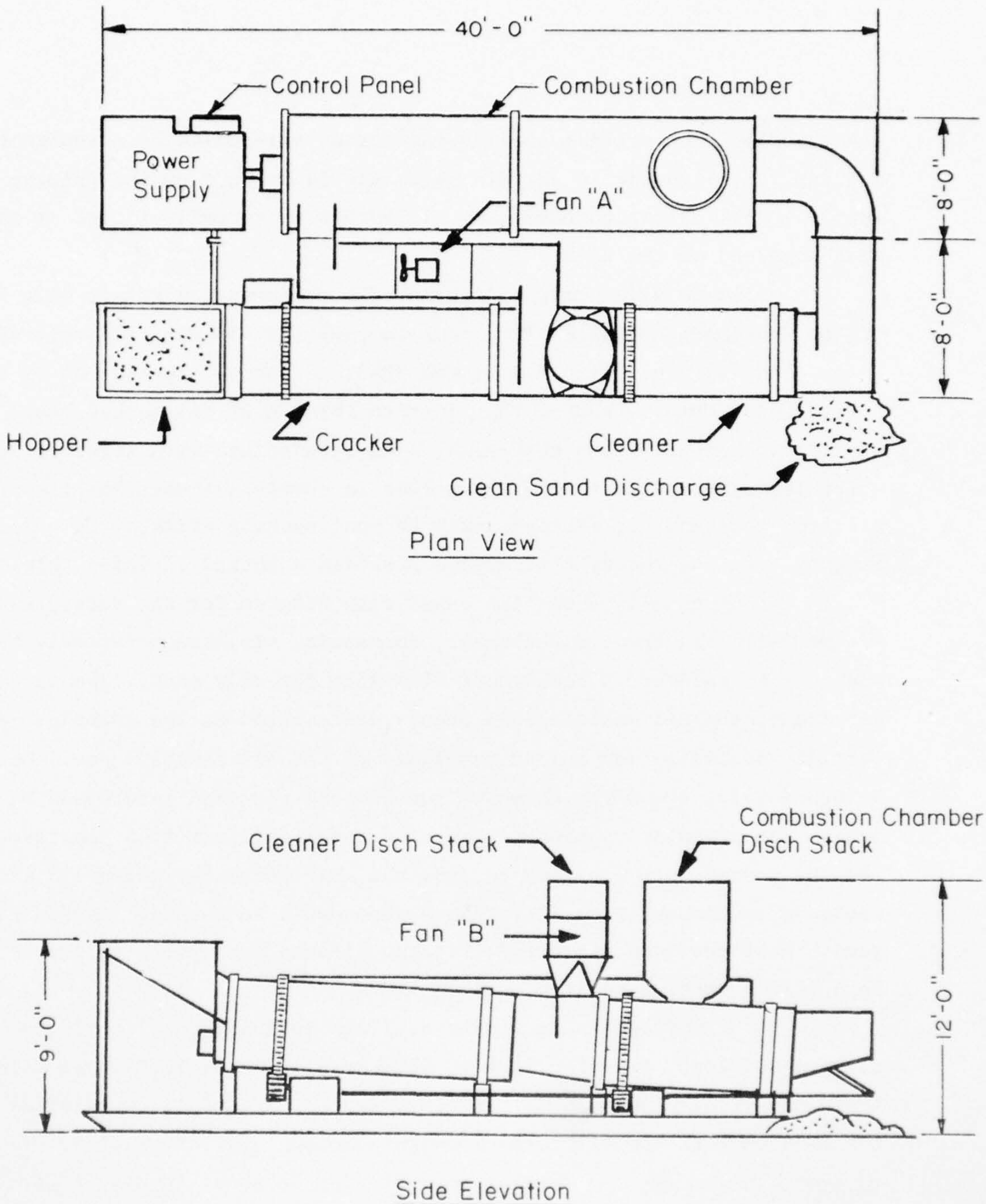


FIGURE 4-11. SCHEMATIC DIAGRAM OF THE ROTARY-KILN-SAND CLEANER DEVELOPED BY THE ENVIROGENICS COMPANY

(from Reference 9)

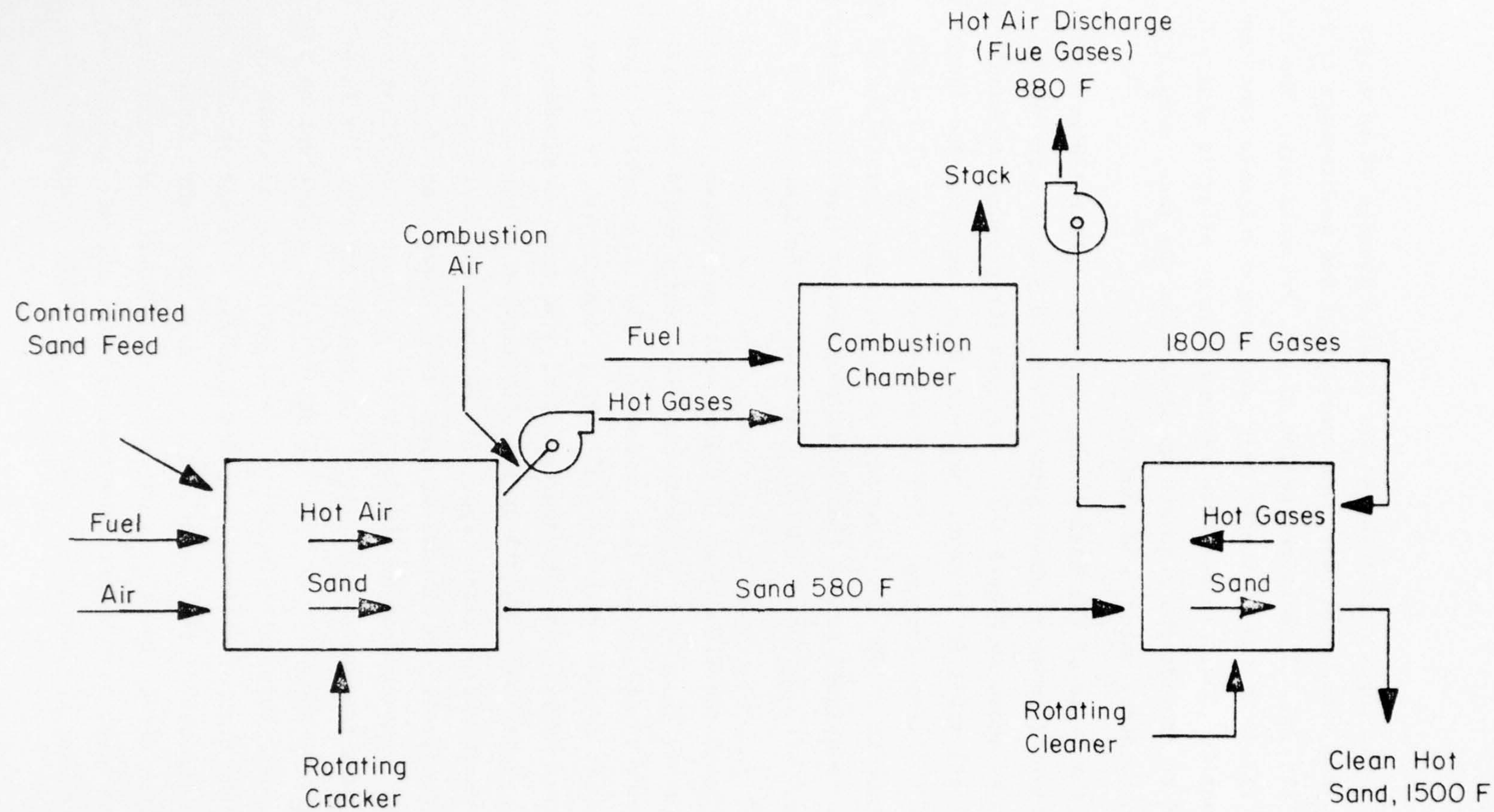


FIGURE 4-12. FLOW DIAGRAM FOR THE ENVIROGENICS ROTARY-KILN-SAND CLEANER (from Reference 9)

cents/ton. If the input contained the anticipated average of 16 weight percent petroleum this would represent operational and maintenance costs of about 3 cents and 1.3 cents per gallon of oil, respectively. The original capital cost (1970) of the 10 ton/hr unit including a suitable feed conveyance system is about $60,000. It has been assumed that an electric generator would be used to provide the required hp needed for the fans, pump, compressor, kiln rotating motor, and controls.

On the basis of the maximum expected oil content (20 percent), the incinerator could dispose of about 5000 lb/hr, or 675 gal/hr, of spilled oil. Two of the units shown in Figure 4-11 are just large enough to handle the 10,000 barrel oil spill in 14 days. However, both the width and length of each unit are too large for the C-130 transport by a factor of 2. The estimated weight is 26,000 lb. However, it is certainly possible that this unit could be redesigned into 4 individual packages of dimensions less than 9 ft x 9 ft x 20 ft, or that a smaller unit could be designed to fit in a C-130 transport.

Although the kiln shown in Figure 4-11 was designed primarily for sand/oil mixtures, it appears possible that the design could be modified for any type mixture of oil, snow, ice, or debris. The first modification may be for a somewhat larger cracker and cleaner (presently 4.5 ft diameter) to allow for larger debris, or more conveniently, some type of shredder at the hopper inlet. Next, for snow/oil or ice/oil mixtures as high as 80 percent, considerable water and/or water vapor will be generated in the cracker unit as presently designed. To dispose of these large quantities of water, it is proposed that the cracker be divided into 2 sections. The first section would merely heat the input debris to a temperature of about 200 F, not hot enough to vaporize the water or pyrolyze the oil, but sufficient to melt all ice and snow. Then this liquid mixture of water and oil could be drained from the cracker while the remaining debris (and soaked oil) could be moved into the second section of the cracker at the higher temperature of about 600 to 700 F. The liquid water and oil mixture could then be collected in a large tank beneath the cracker where the oil would slowly separate to the surface (or a more elaborate water/oil separator could be

used). This oil could then be pumped off the top of the tank and used as fuel in the kiln combustion chamber while the water could be drained from the bottom of the tank to maintain the required oil level at the surface. Figure 4-13 presents the basic flow diagram for this specially designed rotary kiln.

In the second section of the cracker, the hot gases from the pyrolyzing oil would again be ducted to the combustion chamber as shown in Figure 4-13. Then, as for the Envirogenics design, the debris would be moved to the cleaner (incinerator) where the remaining oil and oil-soaked debris would be burned. The ash (and rock, sand, etc.) would then be discharged from the cleaner either directly onto the ground or into some type of container for disposal.

One additional feature which may be included in this new kiln design is to use the water (from the tank or separator) to provide smoke control for the combustion products in the stack. Envirogenics reported that, if sufficient oxygen is provided for combustion, the oil in the influent can be burned with no visible particulate emission. However, the addition of tundra, gravel, driftwood, marine life, etc., to the influent may necessitate further smoke control measures.

This new kiln design would have essentially the same size and weight problems as the Envirogenics design. However, it is certainly feasible to design the various systems components to be transported separately and assembled quickly at a spill site location, or the kiln sections could be designed to dimensions suitable for air transport.

4.4.3 Open Combustion, Pit Type Incinerators

Figure 4-14 shows a design of an open pit incinerator that can be used to dispose of large quantities of oil and oil-soaked debris[10]. The design was originally developed by the du Pont Company for the safe destruction of a solid chemical waste which would have presented an explosion hazard had its destruction been attempted in a conventional enclosed type of incinerator. This figure shows a cross section of the incinerator

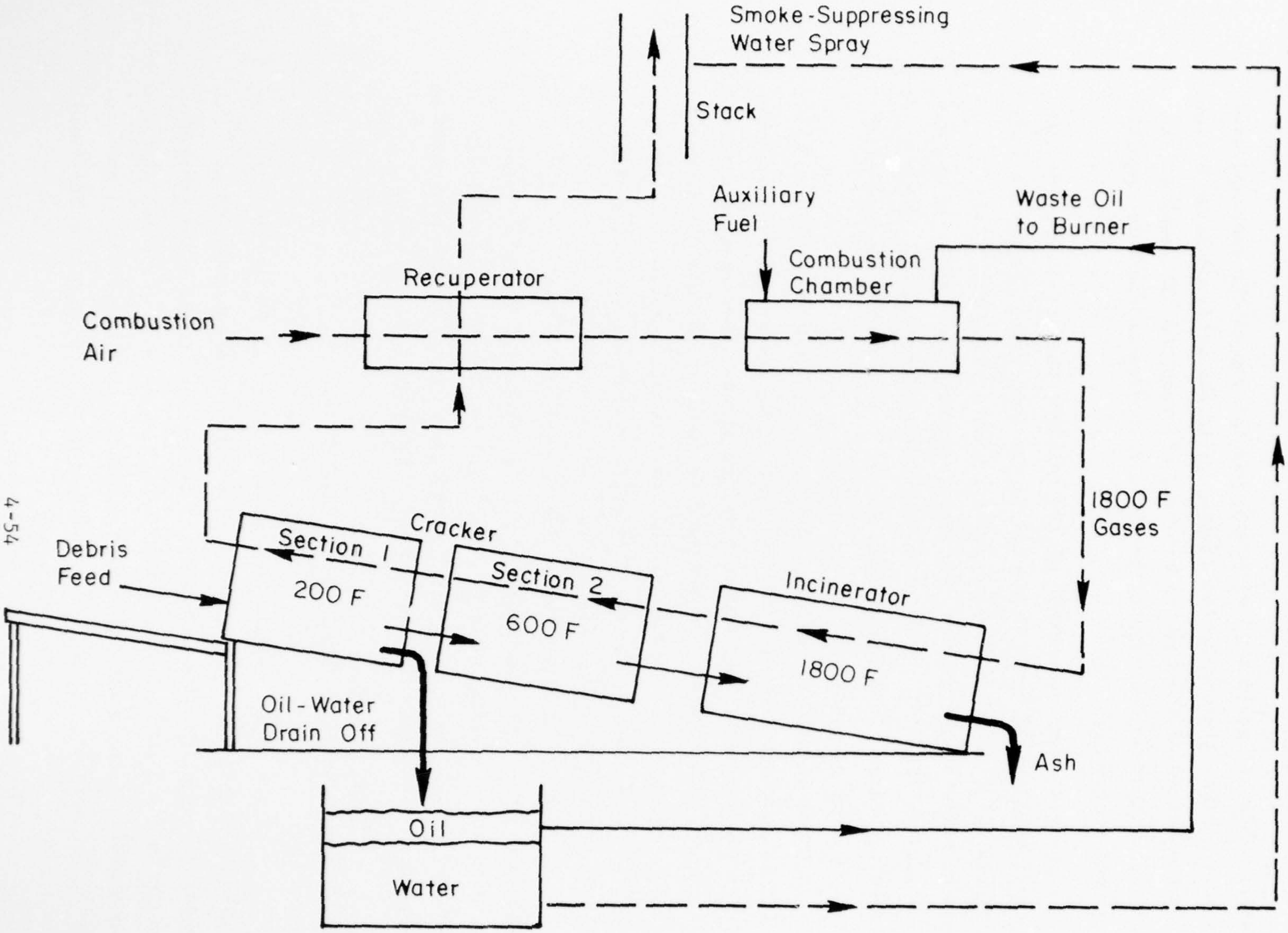


FIGURE 4-13.FLOW CHART FOR ROTARY KILN DESIGNED TO BURN SPILLED OIL AND DEBRIS

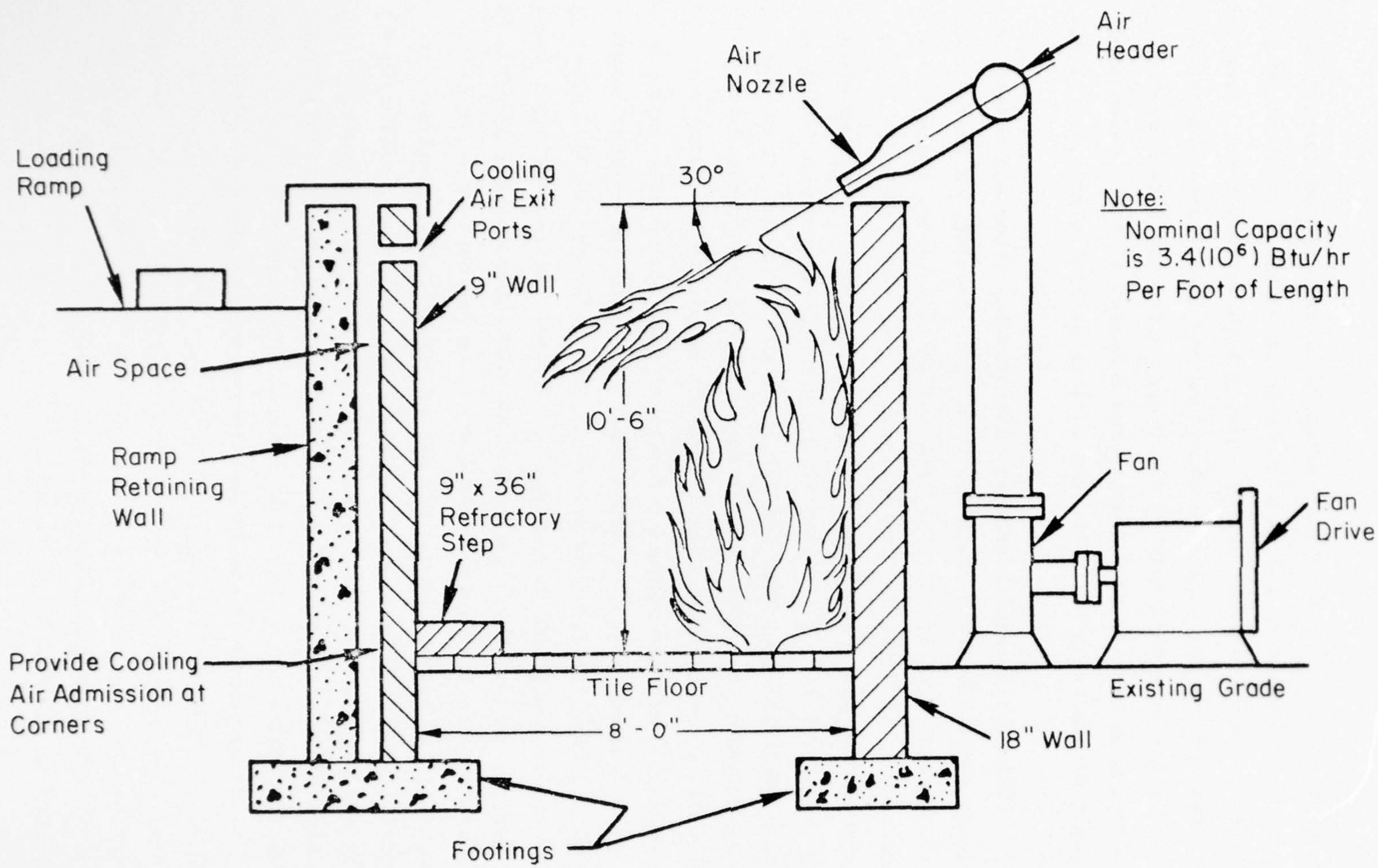


FIGURE 4-14. CROSS SECTION OF THE DU PONT OPEN-PIT INCINERATOR
(from Reference 10)

which has the unique feature of an array of closely spaced nozzles admitting a screen of high-velocity air over the burning zone. Exceptionally good incineration characteristics result, giving high burning rates, long residence times leading to complete combustion, and high flame temperatures. Extensive tests have been made in which many solid and liquid wastes have been burned with equally good results and a number of these units have been built or are being built for the various du Pont plants, both here and abroad.

This incinerator possesses the following favorable characteristics: use of the sky to absorb heat, simplified fuel handling, no grates needed with 100 percent overfire air, no need for skilled labor, low maintenance, and low investment. The du Pont incinerator has been developed for stationary incineration applications. As shown, the overall dimensions are greater than the 9 ft x 9 ft x 20 ft limitation of the C-130 and the method of construction makes it unsuitable for air transport. However, it may be possible to reduce the overall size and weight of this incinerator to meet the portability requirements for arctic oil spills by utilizing air-cooled metal walls. Since the nominal capacity of this incinerator is 3.4×10^6 Btu/hr per foot of length, it would require a total incinerator length of about 5 ft for the 1,000 barrel spill, 50 ft for the 10,000 barrel spill, and 250 ft for the 50,000 barrel spill. For the smaller spills, a smaller cross section and greater length would be preferable. These lengths, however, are based on this incinerator's capacity for burning solid wastes and its capacity for burning liquid oil may be significantly greater. This incinerator should be capable of handling large volumes of debris in addition to the liquid oil. This type of incinerator would be practical for small and medium size spills (up to 10,000 barrels), but should probably be used in combination with a high-volume liquid burner for large spills.

An outgrowth of the du Pont incinerator is the open pit incinerator shown in Figure 4-15. This incinerator was designed by Kenting Oilfield Services, Ltd., of Edmonton to dispose of oilfield waste[11]. The unit incinerates wax, hay, crude oil, and sludge without producing visible emissions. Complete combustion results from exposure to the 2,200°F temperature in the combustion chamber.

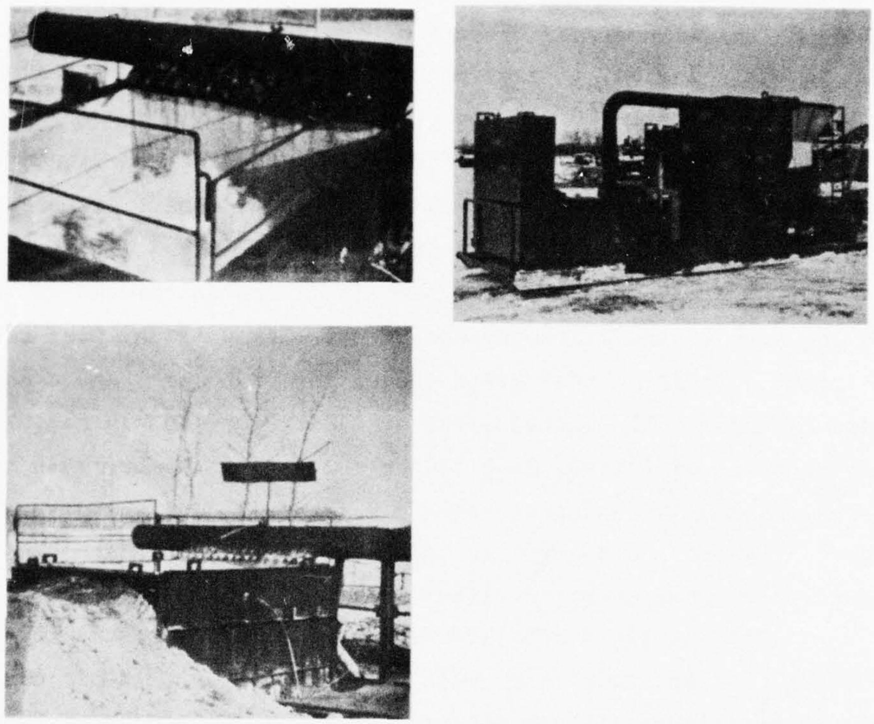


FIGURE 4-15 PHOTOGRAPHS OF KENTING OPEN-PIT INCINERATORS FOR BURNING OILY WASTES (FROM REFERENCE 11)

In March, 1974, Kenting Oilfield Services completed testing a prototype incinerator designed to burn off beach sands and gravels. Engineering of the full scale production system is presently underway. Analysis of emissions was conducted by the Research Council of Alberta and met Federal Department of the Environment regulations. The results indicated that with proper operation, the unit could be operated with smoke levels below No. 1 Ringlemann. The tests indicated that hydrocarbons average below 50 ppm and odor is negligible.

The Kenting "Kleen-Up" incinerator has been designed to permit easy transportation to a remote oil spill site. Units are presently being built having pit dimensions of 7 ft x 9 ft x 8 ft and a total overall weight of about 30,000 lb. The unit weight can be reduced by temporarily removing some of the auxiliary equipment. The unit utilizes continuous loading by a reciprocating grate feeder from a hopper, and a continuous solids discharge. In addition, an auxiliary fuel supply has been added which provides additional heat to the combustion chamber when burning material with a low heating value. Test results indicated that a heavy crude having the characteristics of Bunker C could be burned with up to 40 percent water without auxiliary fuel and without visible smoke.

Data obtained from the Kenting Oilfield Services representative indicates that an incinerator with a 7 ft x 9 ft x 8-ft pit could handle about 20 barrels of oil per hour (about 2.0×10^6 Btu/hr/sq ft). One of these units could handle the total oil and debris from a spill up to about 7,000 barrels (in a 14-day period). The large 50,000 barrel spill would require 7 units operating full time for 14 days. Kenting has estimated the cost (1974) of each unit at about $36,000 to $45,000. Thus, it appears that a single Kenting "Kleen-Up" incinerator is certainly feasible for burning oil and debris from all spills up to about 10,000 barrels.

The du Pont or Kenting incinerators discussed above work by directing a row of jets of combustion air over a rectangular pit lined with refractory. It may prove feasible to construct a reasonably smokeless incinerator by providing a lightweight, portable air duct with jets in the side, to direct air into a V-shaped trench bulldozed into the ground.

If such a trench was 50 percent as effective for burning oil as the Kenting incinerator, it would achieve a burning rate of 1.0×10^6 Btu hr/sq ft. Thus, a 10 ft x 94 ft trench could burn 50,000 barrels of oil in 14 days, or 21,000 barrels of oil could be burned in a single day in a 10 ft x 500-ft trench.

This could only be done where the ground is suitable--sand, gravel, or earth, and may not be practical in permafrost because heat would be conducted into the ground for some distance on either side of the trench.

The air supply to the duct could be taken as the exhaust from a small turbojet engine. Exhaust gas contains about 17 percent oxygen, and is available at a temperature near 1200 F and pressure as high as would be useful for air jets. The ducting would be made in sections, connected with V-band couplings. A typical turbojet engine which may be used would have the following characteristics:

Engine Thrust, lb	Engine Air Flow, lb/sec	Ducted Air Flow, lb/sec (Assuming an Air Entrainment Factor of 4)	Spilled Oil Burn Rate, lb/sec	BBL/Day
5000	100	400	74	21,000

4.4.4 Open Flame Liquid Oil Burners

For burning large quantities of liquid oil with adequate smoke suppression, the commercially available open flame waste oil burner appears to be the practical choice. Figure 4-16 shows a photograph of a waste oil burner developed by the National Airoil Burner Company (NAO) and sold commercially (or leased) by the Otis Engineering Corporation of Dallas, Texas[12]. This unit (Model CB-12) is used to burn away as much as 12,000 bbl/day of unrefinable crude oil during offshore well tests. This test oil, brought up by offshore drilling platforms while checking the potential capacity of new wells, usually contains water, mud, drilling compounds, rocks, and other impurities that would foul processing equipment.

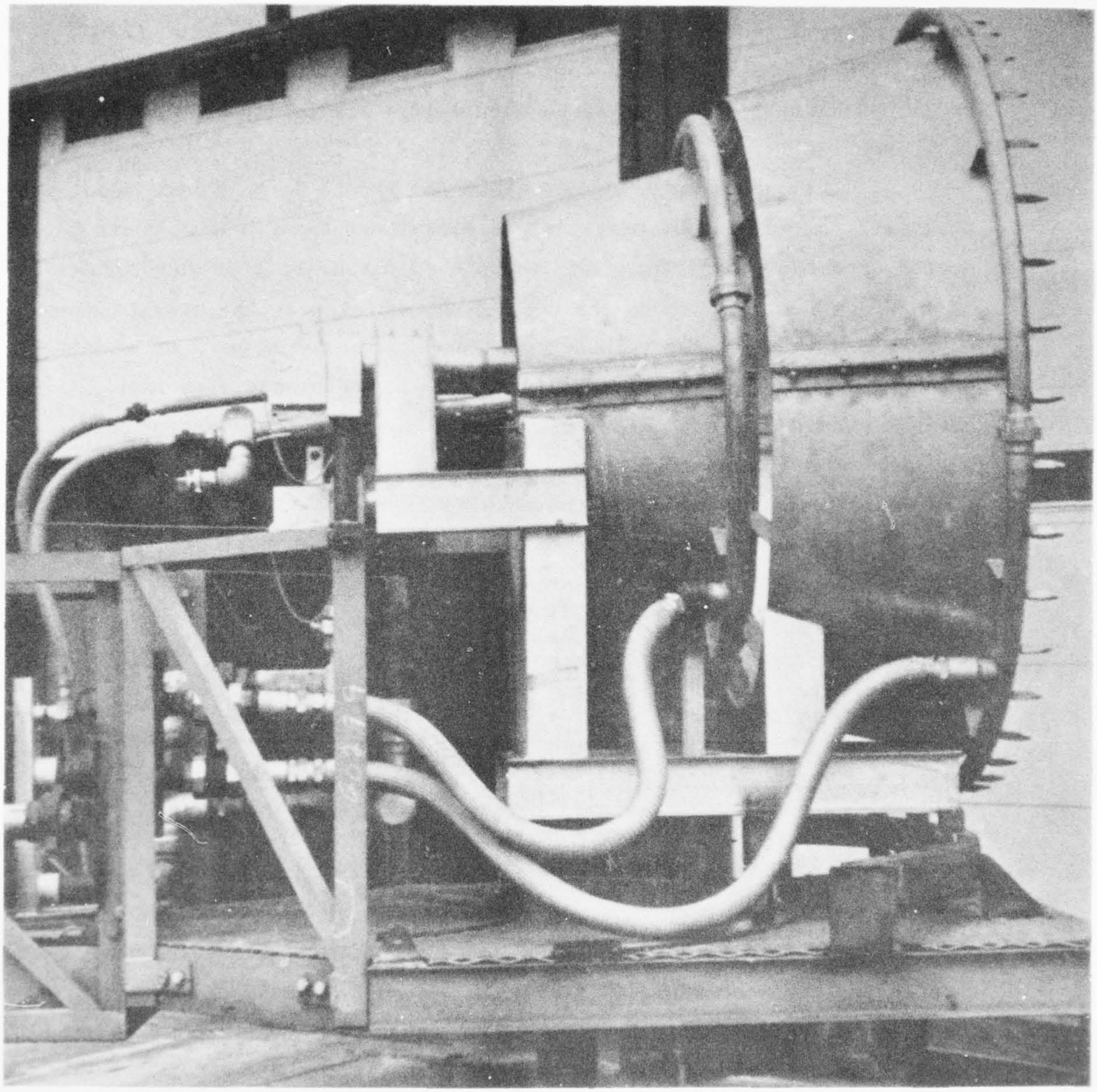


FIGURE 4-16. PHOTOGRAPH OF THE NAO/OTIS CB-12 WASTE OIL BURNER
(FROM REFERENCE 12)

AD-A032 749 BATTELLE MEMORIAL INST RICHLAND WASH PACIFIC NORTHWE--ETC F/G 13/2
TEMPORARY STORAGE AND ULTIMATE DISPOSAL OF OIL RECOVERED FROM S--ETC(U)
DEC 75 P L PETERSON, R A YANO, M M ORGILL DOT-CG-23223-A

UNCLASSIFIED USCG-D-181-75 NL

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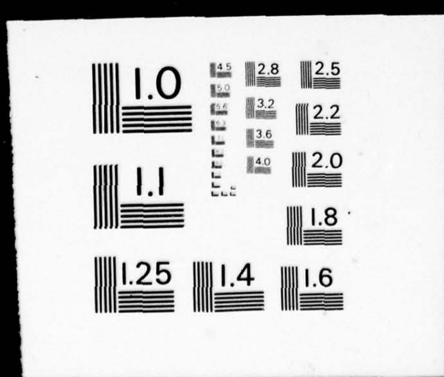

This burner uses compressed air to atomize the waste oil and does not use a fan for combustion air, which is aspirated into the oil. Although part of the flame is fuel rich, smoke is minimized by spraying water into the flame. NAO's well test burner consumes petroleum in daily quantities ranging from 250 to 12,000 barrels. Firing the largest design burner releases a tremendous amount of heat, especially at full capacity with its flame 165 feet long and 15 to 20 feet in diameter. The burner's 3 billion Btu per hour firing rate is equivalent to the combined heat input of 6 medium sized refineries, or a 300 megawatt power plant. Figure 4-17 presents diagrams showing the end view and side elevations of the large burner.

Surprisingly, despite the great volume of oil consumed, the burner can be smokeless, even at high firing rates. Three major factors combine to achieve the complete combustion necessary for eliminating smoke; good oil atomization, combustion air inspirated over the length of the flame, and water spray to control fuel cracking in the rich part of the flame. High oil pressure is needed for good oil atomization with an oil pump providing the atomizing pressure. Oil pressure varies with the firing rate, to a maximum of 350 psi. The oil atomizer uses compressed air for atomization. The air is supplied at 100-psig pressure from an air compressor. A constant 900-cfm volume is maintained when the burner uses all of its three oil guns. When only two guns are firing, air volume is proportionally reduced. The air is used in an internal-atomizing swirl-type oil atomizer having openings large enough to pass 1/4-inch stones. This type of atomizer usually requires preheating of the oil to a temperature that results in a viscosity of 15-20 centistokes. This low viscosity requirement will almost certainly necessitate preheating spilled arctic oil prior to atomization.

The high-velocity stream of atomized oil and air rushes into a "combustion chamber" (actually a flameholder) consisting of two conical pieces or "cans". Large volumes of air are drawn with the mixture through the wide annular aperture separating the two cans. Water is essential to create the proper conditions for combustion without smoke. At the maximum, 12,000-barrel daily firing rate, approximately equal amounts of oil and seawater are consumed. With the burner firing at lower rates, more water

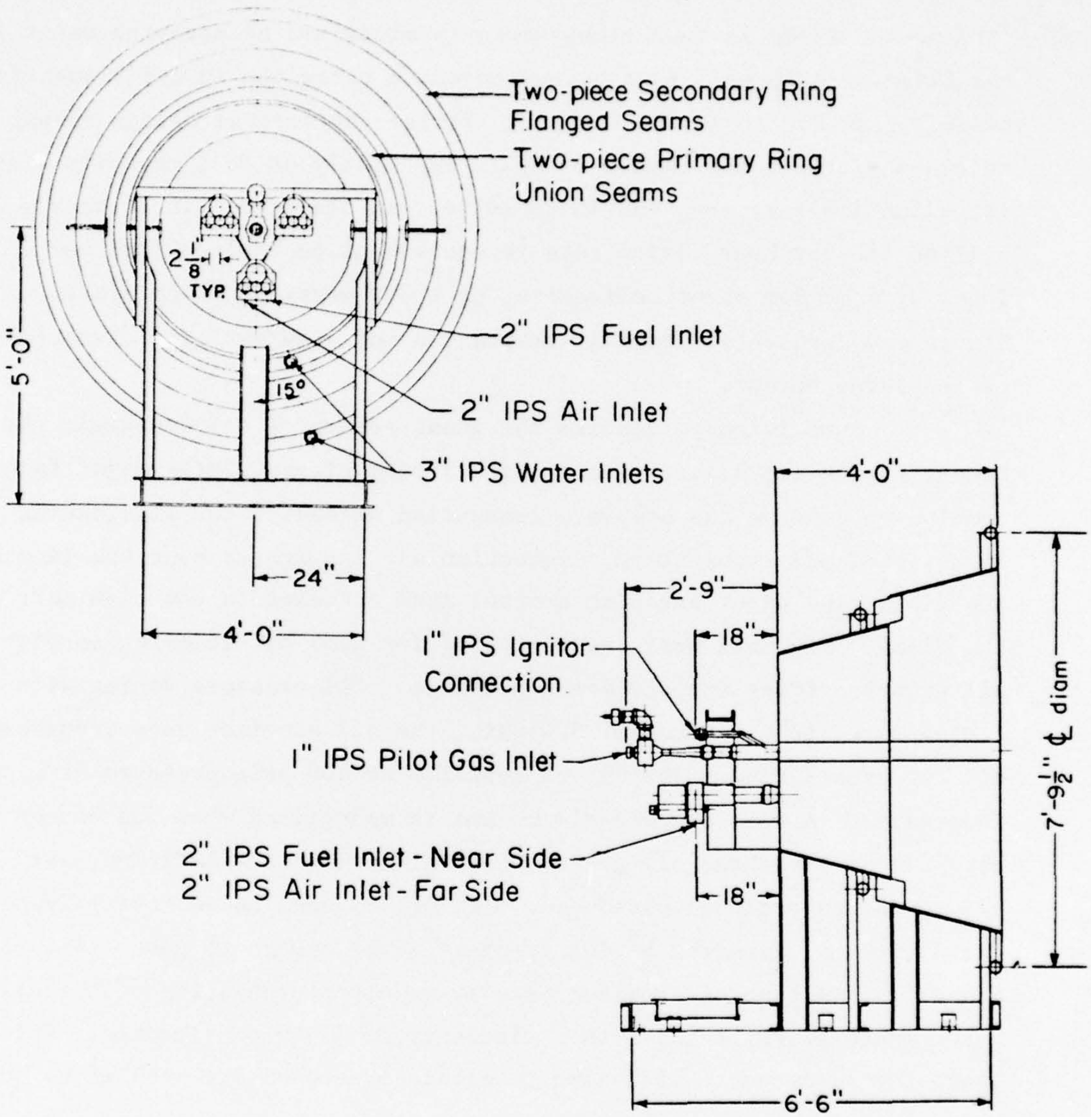

FIGURE 4-17. DESIGN SKETCHES OF THE NAO/OTIS CB-12 WASTE OIL BURNER (FROM REFERENCE 12)

is used than oil. The water-injection system consists of two rings of spray nozzles. One water ring is located in the aperture between the two burner cans. The larger ring is mounted around the periphery of the larger can at its exit. Water is pumped through these rings into the flame at pressures ranging from 125 to 300 psi. Close control of water flow is necessary for complete elimination of smoke. Too little water will fail to stop the black smoke; too much results in a thick gray smoke, from quenching of the flame. The water accomplishes its purpose by injecting air to improve mixing and combustion, and through a cooling action that minimizes cracking of oil compounds. The effect of water spray is the same as for water sprays over the surface of a burning oil pool. The burner weighs 1175 pounds and can be separated into two sections for air transport by removing the bolts from the mating horizontal flanges of the cans.

A smaller version of the NAO-Otis CB-12 burner is the CB-4 burner which will handle up to 4000 barrels of oil per day while burning smoke free. This burner requires the oil to be pressurized to 200 psi and requires 750 SCFM of air at 100 psig and a 6 to 1 water to oil ratio (at the 4000 barrel/day firing rate). At only a 1500 barrel/day firing rate, no water would be required for smoke-free burning. This burner will handle oil with up to 50 percent water.

Another waste oil burner that is commercially available at the present time is shown in Figure 4-18. This burner was developed by the John Zink Company and is sold commercially by the Baker Oil Tools Company (Houston, Texas). This burner was also developed to dispose of large quantities of crude oil or condensate produced during the production testing of oil or gas wells. It has been designed to handle oil rates up to 10,000 barrels per day under smokeless operating conditions. This burner operates on the same principle as the NAO burner, using high pressure air (or gas) to atomize the oil and high pressure water to eliminate smoke. This burner consists of an atomizing head surrounded by a shroud through which some of the primary combustion air is blown from a close mounted fan (7200 SCFM at 2 in. water). The atomizing head has 50 mixing ports designed to pass 10,000 barrels per day of crude oil at a back pressure

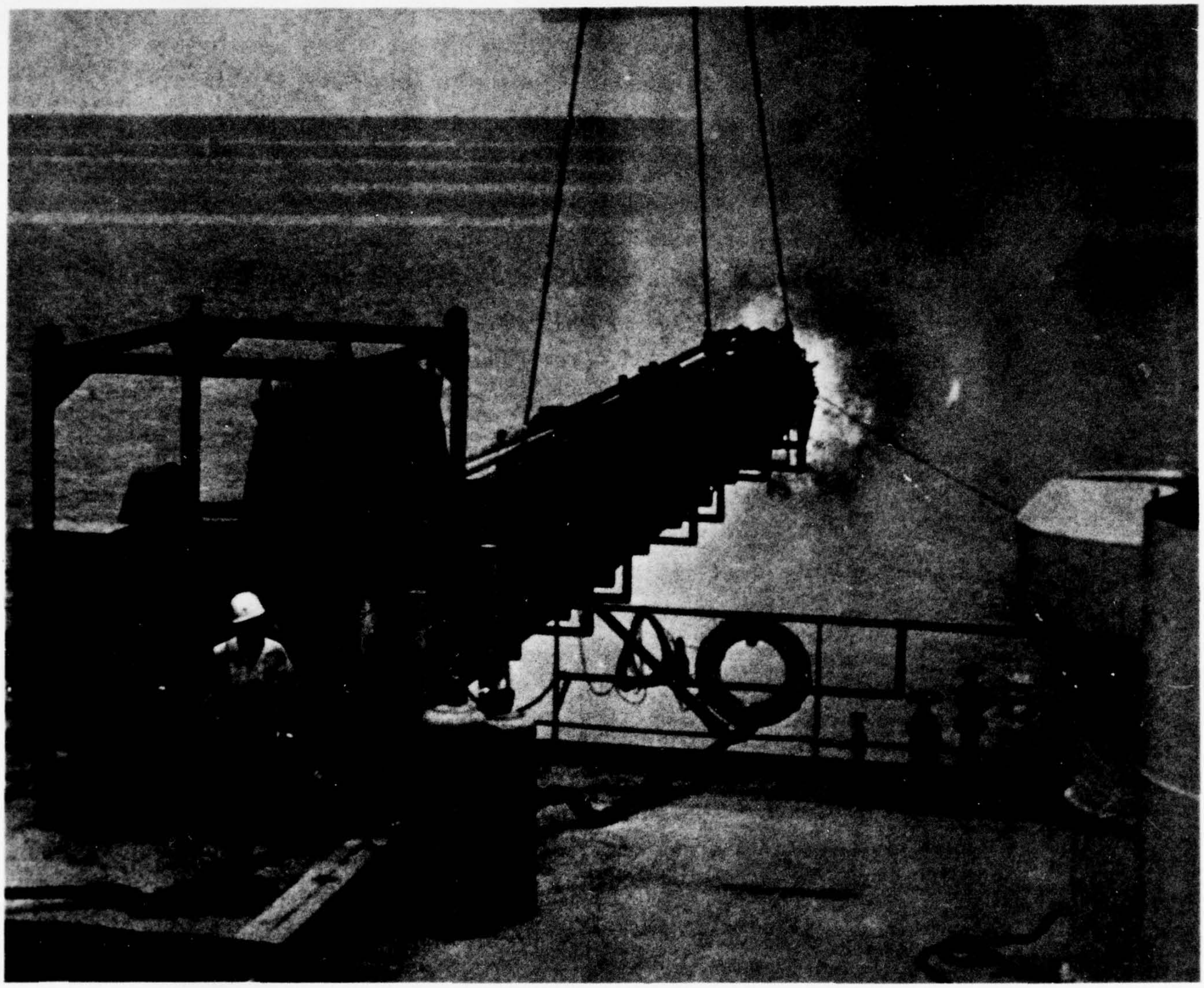

FIGURE 4-18. PHOTOGRAPH OF THE BAKER/ZINK "MAXI-MINI" WASTE-OIL BURNER (FROM REFERENCE 13)

of psi. Atomization is achieved by means of a "Y" type atomizer using either compressed air or gas (at 80 psig). The requirement of compressed air/gas is approximately 3 percent by weight of the oil, that is, 1200 SCFM at a 10,000 bbl/day crude rate.

The burner incorporates two constant ignition gas pilots, each complete with a pilot ignition system, and two water ring manifolds, one spraying water radially to reduce the back radiation of heat, and one spraying forward into the flame to reduce smoke formation. The water shield for heat radiation production comprises a water ring manifold with 18 radial spray nozzles each capable of delivering 10.8 gal/min at 100 psig pressure (approximately 4.6 bbl/min or 6665 bbl/day). The water injection manifold for smokeless combustion comprises a water ring manifold with forward jetting axial spray nozzles also capable of delivering 10.8 gal/min at 100 psig pressure. The overall weight of the burner, including fan and pivot mounting, is approximately 1288 pounds.

It appears that the NAO or John Zink burner could easily handle even the largest oil spill (50,000 barrels) in a period of 4 to 5 days. To operate the burner under smokeless conditions may require a water supply. The weight and size of the burner are such that each burner with all auxiliary equipment (pumps, generator, etc.) might be loaded onto one or two C-130 transports. For an oil spill consisting of only oil with small bits of rock, sand, and debris, this type burner would be all that is required. However, for spills involving significant amounts of larger solid materials, an additional incinerating device will be required.

The principal development effort needed to use such a burner will be in the area of oil conditioning, heating, and pumping to supply the burner. The NAO and Zink production systems include electric-motor driven piston compressors, fans, and pumps for oil and water. Consideration should be given to utilizing a gas turbine for motive power, either as a generator for electric-driven pumps and compressor, or for direct drive of these units from a common gear box. The direct drive would be much smaller and lighter than electrice drive, but electric drive would provide greater flexibility in positioning of pumps around a spill. Although gas turbines are relatively expensive, they are very compact and light in weight, major considerations for air transportability. The gas turbine can also provide hot, high pressure, atomizing air.

Burners designed for boilers in utility stations and industrial power plants are similar to the NAO burner except that they usually utilize steam atomization instead of compressed-air atomization (these are interchangeable for practical purposes). In addition, these burners are much smaller at about 200 to 300 million Btu/hr, and cannot handle the type of debris that the NAO and Zink burner can. These burners can operate on as little as 2 percent excess air and require only about 0.04 lb steam/lb oil for effective atomization. It is possible that these types of burners could be used to handle small- and medium-size oil spills; however, they have not been designed for the "dirty" oil or rough operating conditions that have been designed into the larger burners discussed above.

Another burner which may be feasible for cleanly burning large volumes of oil is one which uses a large gas turbine type burner. Figure 4-19 presents a conceptual design sketch of a burner of this type. As shown in the figure, the diameter of the burner would be limited by aircraft cargo space dimensions to about 8 ft and the burner length would be between 8 and 12 ft. The construction could be of air-cooled sheet metal, resulting in extremely lightweight for the combustor structure. Air would be supplied at a pressure of 8 to 12 in water gage and in a quantity near the stoichiometric ratio for the oil firing rate. Typical air supply for an 8-ft diameter combustor would be 5000 ft^3/sec or 385 lb/sec. This is sufficient to burn oil at a rate of 25 lb/sec, or 92,000 lb/hr. This is equivalent to 285 bbl/hr, or 6800 bbl/day.

The fan power needed to supply combustion air would be approximately 700 hp, based on 80 percent fan efficiency. The only advantage of this enclosed-flame burner over the open-flame burner (such as the NAO or Zink burner) is that the amount of flame leaving the burner would be very small, extending a distance of no more than 8 ft with a diameter of 8 ft. The open-flame burner, in contrast, requires no combustion air fan but produces a flame over 100 ft long and 30 ft in diameter. The open-flame burner requires a large supply of water to avoid smoke, whereas the enclosed-flame burner requires no water. The size and weight of the can combustor system could be minimized by using a gas turbine as the source of air. A 700 hp

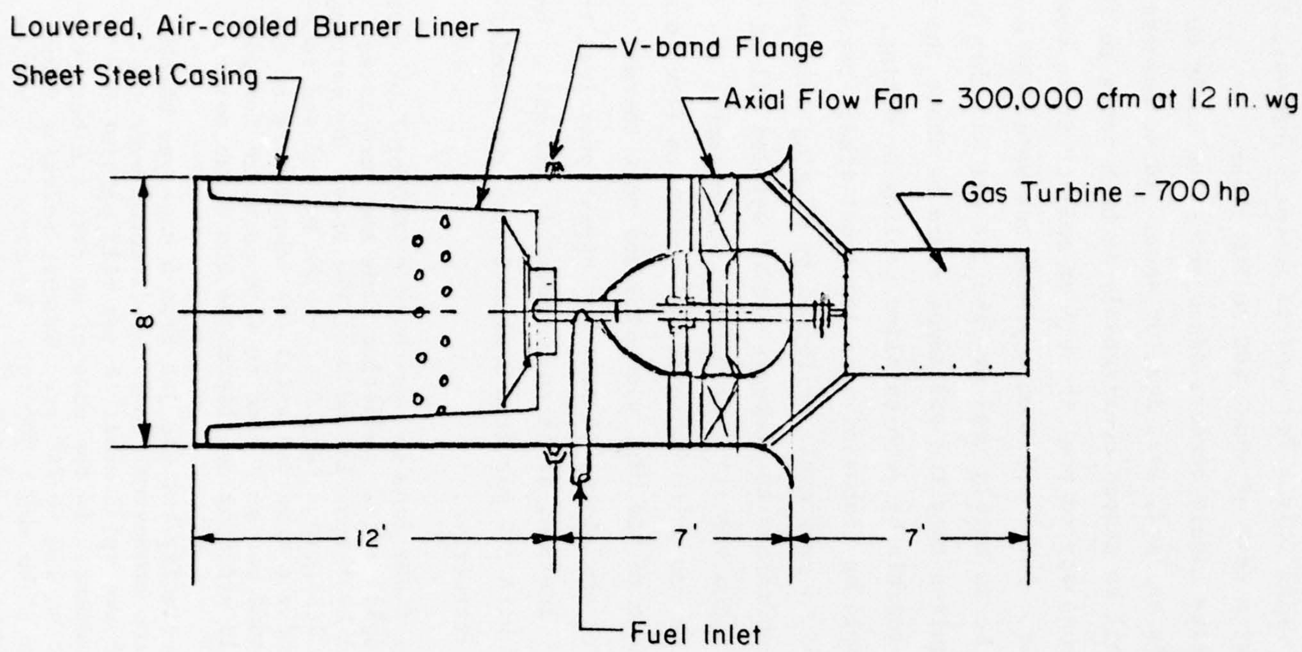

FIGURE 4-19. CONCEPTUAL DESIGN OF LARGE GAS-TURBINE-TYPE BURNER FOR LIQUID CRUDE OIL
Burning Capacity--90,000 lb/hr or 6700 bbl/day

engine could drive an axial-flow fan to move the large quantity of air at low pressure, and would weigh only a few hundred pounds. However, it would consume jet fuel at a rate of about 400 to 500 lb/hr.

The high capacity liquid burners discussed above could be easily transported to oil spills on land, sea, ice, or snow. These burners, however, require that the oil be pumped continuously at high rates to the burner. Therefore, it will be necessary to pool the oil or collect it in some way and pump it to the burner. For a spill on anything but water the easiest collection method would be to merely pool or dike the oil and then pump it to the burner. This requires that the oil temperature be above the pour point and that the land terrain be such to allow pooling or diking. For hilly terrain the oil could be channeled to a low level diked area whereas for relatively level land, a pool could be formed by digging and channeling.

Under arctic conditions the temperature of spilled oil on the ground would usually be below the oil pour point. Furthermore, the oil may be mixed with snow and ice, so as to be solid and unable to flow into a collection system. Because of the high viscosity and poor thermal conductivity of oil or oil-water emulsions, it does not appear practical to heat them in heat exchangers. Instead, it is suggested that the oil be heated on the ground by contact with hot gas from combustion of the burning oil. Three approaches appear attractive.

(1) Direct the flame from an open burner (NAO or Zink type) over the spill area. Radiation from the very large flame will heat the oil and melt the snow. By varying the flame direction (height above the ground and rotation around the vertical axis) the temperature of oil on the ground can be raised to a temperature for good flow, while avoiding heating above the flash point.

(2) The high-velocity hot gas jet from a can-type burner (gas turbine combustor) could be directed over the surface of the spill area. A jet will persist for 20 to 30 diameters. In the case of an 8-ft can burner, this would be 160 to 240 ft. Exhaust velocity from the can would be about 300 fps. By control of burner direction and angle of tilt, a large area could be heated to the point of permitting oil flow without ignition. The flowing oil could be collected in a pool from which it would be pumped to the burner. It is

conceivable that, with the large burner described, all of the oil within a 250-ft radius of the burner could be melted and directed to the burner. The burner could then be moved to a new site to liquify more oil.

(3) The oil and debris could be transported to a pit, heated, and pumped to the burner. It is possible that an immersion-type burner could be used to liquify and heat the water and oil. Such a burner has been developed for snow melting by Thermal Research and Engineering Company of Conshahocton, Pennsylvania. This burner consists of a combustion chamber, fan, and exhaust duct which exhausts the hot combustion gases beneath the surface of the snow, or in the application here, beneath the surface of the pool of oil and serves to warm the oil by direct contact with the exhaust gases.

For a spill on water, a skimming device will probably be used to collect the oil. Oil could possibly be pumped directly from the skimmer to a burner if the water content was low enough.

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4.5 IN-SITU BURNING

The techniques to be evaluated for burning spilled oil (and debris) are broken down into two main categories: (1) in-situ, open burning, and (2) burning collected oil in burners and/or incinerators.

Where feasible, open, in-situ burning should be much easier and require less manpower and equipment than burning collected oil in burners or incinerators; however, there may be geological, climatological, or ecological conditions which would prevent in-situ burning. Open in-situ burning will be examined to determine the manner of burning and the oil spills conditions where it may be applicable. Various methods to promote clean in-situ burning will also be investigated. (The burning of collected oil to determine how this method can be used to handle those spills not suitable for in-situ burning was discussed in Section 4.4).

4.5.1 Computation of In-Situ Burning Times

The direct, in-situ burning of petroleum and its derivatives has been tried at one time or another in many major oil spills with varying degrees of success. The classical work on free-burning fires of large fuel oil spills was performed by Blinov and Khudiakov[1]. This work was reviewed and organized into a compact form by Hottel[2]. The data given by Hottel indicates that the liquid burning rate of fuel oil per unit area becomes constant at a pool size above about 5 ft in diameter. For gasoline a value of about 4 mm/min (0.00022 ft/sec) is obtained, and for diesel fuel a slightly lower value is obtained. Burgess and coworkers[3] obtained a linear relation between the regression rate of a large burning pool and the ratio of net heat of combustion to the "sensible" heat of vaporization. For hydrocarbons, this relation gives a lowering of the regression rate as the vaporization temperature increases. Therefore, the regression rate for Prudhoe Bay crude oil, especially where weathered, will be less than the 4 mm/min as given by Hottel.

Nevertheless, assuming a regression rate of about 4 mm/min and an oil heat of combustion of 140,000 Btu/gal, the burning rate is calculated to be about 8.2×10^5 Btu/hr ft^2. Allowing for a reduction due to the use of a high regression rate, this burn rate is found to be about that used in conventional stoker furnace design (500,000 Btu/hr ft^2, Ref. 4).

McMinn[5] suggested that a crude oil spill on ice would spread out to a minimum thickness of about 0.1 ft, due to the roughness height of the ice. Using this minimum thickness, Table 4-3 gives the area (ft^2) and the diameter (ft) of the four oil spill sizes to be examined in this study. The burn time shown in the table is that discussed above--namely, the time to burn down through 0.1 ft of oil at a rate of 4 mm/min. As shown there, the burning time for all four spills would be about 7.6 minutes.

The burn time, however, considers the ignition to be instantaneous; that is, ignition occurs over the entire surface of the pool simultaneously. In reality, ignition will likely be initiated at one edge of the pool and will spread slowly throughout the pool. In particular, the spread rate with no wind would be of prime interest as this should give the maximum spread time. This flame spread phenomena and the flame spread times, shown in Table 4-3, will be discussed below.

Two types of flame spread have been observed. If the temperature of the fuel is above the fire point (close to flash point), the vapor phase controls and the flame will spread at a rate depending on the stoichiometry of the vapor-air mixture. The rate is comparable with the laminar burning velocity, and somewhat above it because of the accelerating action and turbulence action of the burning gas. For propanol, butanol, and iso-pentanol, a value of about 2 meters/sec has been observed. When the fuel temperature is below the fire point, the liquid phase controls; that is, the heat conduction through the fuel controls the flame expansion velocity. The value is highly dependent on temperature and is at least an order of magnitude less than the comparable flashing flame velocity. It should be noted that adding a highly volatile fuel to the base fuel will not necessarily cause the flame to propagate through the base fuel; the volatile portion may flash and burn off and the entire flame go out. This is especially true

TABLE 4-3.

FREE-BURNING FIRE TIMES FOR ARCTIC OIL SPILLS

Spill Size				Burn Time	Flame Spread	
Barrels of Oil	Heating Value, Btu	Area, ft^2	Diameter, ft	Down Burn Only, min	Vapor Controlled, min	Liquid Controlled, hr
100	6×10^8	5,610	84	7.6	0.21	1.4
1,000	6×10^9	56,100	267	7.6	0.68	4.5
10,000	6×10^{10}	561,000	845	7.6	2.15	14.3
50,000	3×10^{11}	2,805,000	1,890	7.6	4.8	32.0

for a thin film on a water surface, which acts to quench the flame. Tests have shown that massive additions of charcoal helps in this case, preventing downward heat loss and absorbing radiant energy.

The flame spread times shown in Table 4-3 were calculated based on a vapor controlled spread rate of 2 meters/sec and a liquid controlled spread rate of 0.5 cm/sec (based on isopentol, which has a flash point comparable to diesel fuel at 20 C). As shown, the vapor controlled spread times are quite short, being only 4.8 minutes for even the largest spill. If this 4.8 minute spread time is added to the 7.6 minute down burn time, the total burn time for even the largest spill is only about 12 minutes. However, when the spread rate is controlled by the liquid oil heat conduction and not the vapor-air mixture, the spread rate increases to about 32 hours for the largest spill. Even though this spread time is 400 times that of the vapor controlled spread time, it still is well within the allowable time period for eliminating the large oil spill. These flame spread times could be halved by igniting the center of the pool or by igniting points on opposite edges of the pool, or the flame spread times could be reduced fourfold by igniting both the center of the pool and evenly spaced points along the pool edge. In addition, it should be emphasized that these times were determined assuming no wind, a factor which may serve to increase the flame spread rate several fold--or on the other hand, may serve to blow the flame completely out if high enough. To determine the feasibility of in-situ free burning in the Arctic, accurate flame spread rate data, including the effects of wind, will be required.

4.5.2 In-Situ Burning Experiments

To assess the possibilities of in-situ, open burning in the Arctic, the Canadian Government conducted tests[6] on various oil spills at Deception Bay in the Hudson Straits during 1973. Two 10 x 10 foot test pools five inches deep were cut into the surface of the sea ice. For the first test, approximately 35 gallons of reclaimed oil was poured into the pool, and the fuel was ignited by burning diesel-fuel-soaked rag wicks. Under calm

conditions the burning was vigorous and produced substantial smoke. The burning period was approximately three to four minutes and the residue amounted to less than 1 percent of the initial oil weight. For the second test, 45 gallons of oil was poured into the pool and allowed to remain for one hour. The wind velocity was at 30 knots. When a burning wick was placed downwind, the fire did not spread upwind. The upwind edge of the pool was then ignited and the flames spread quickly across the entire surface. The total burning period was about 25 minutes. The oil in the center of the pool burned quickly but some of the edges of the pool continued burning after the major part of the oil had been consumed. It became apparent that the porous edge of the surface ice acted as a wick.

This on-site burning was possible because both the wind and the ice acted as an effective barrier which held the oil in a thick enough layer to burn. If ice had not been present, the oil would probably have spread over the sea to a thin film. If the oil film is too thin, it will not burn because the water cools the oil and slows its evaporation to an extent that combustion cannot be maintained.

In a spill at Deception Bay[7] in June, 1970, 367,000 gallons of Arctic diesel fuel and 59,000 gallons of gasoline were completely burned, both directly on the water(where it was contained by the nearshore ice)and after pumping onto the sea ice. It was found that the containment provided by the ice was favorable as it permitted easy and complete pumping and/or burning of the oil. Pumping oil onto the sea ice provided a location of the burn site away from the original oil tank farm and the tundra, both of which could conceivably have been set on fire. The clean-up technique used in this spill, of course, depended somewhat on the character of the oil, i.e., diesel fuel and gasoline. However, heavier, less volatile Arctic crude should also burn under similar favorable conditions.

Glaeser and Vance[8] performed open in-situ burning experiments by releasing small quantities of Prudhoe Bay crude oil to simulate oil spills on a small scale. Spills were made both on ice and on melt ponds, and ignition was made of both fresh oil and oil which had been aged up to 6 days. Burning agents (fumed silica and glass bead), as well as straw, were tested as combustion promoters.

Table 4-4 summarizes the burning experiments and the measurements made by Glaeser and Vance. The average flame height was measured with a transit and the burning periods were measured from ignition to burnout. In all cases the oil was ignited by tossing a lighted rag soaked in diesel oil into the pool of oil. Both the fresh and aged crude oil ignited quickly without any further effort and burned vigorously. If a spill were lighted on the downwind side, flames would quickly travel upwind until the entire pool was burning. It was observed that oil pools which were burning on ice would provide enough heat to the surroundings to form channels which drained water and burning oil to lower areas. Enough heat was transmitted to the water under the burning oil for boiling to occur, which effectively atomized the oil. In all cases a large amount of heavy, black smoke was produced. However, no fallout of soot was found on the ice near the burns.

The use of burning agents made no noticeable difference; they were not needed for this particular crude oil. It is possible that, in each individual burn, the burning agent had some effect on the residue, but the variations among burns were large enough to obscure the effect. Hay was burned on a spill after it had lain on the oil for 24 hours. Again little effect was observed during the burn. However, the residue consisted mainly of what appeared to be charred straw with apparently less oil than for other experiments. Attempts were also made to ignite thin slicks. Burning was attained with a burning agent; however, the wind quickly forced the oil into pools thick enough to support combustion without the presence of the burning agent.

The residue from all the burning tests was a heavy tar-like substance. Estimates of the amount of residue left varied from 2 to 10 percent of the original volume. Removing the residue proved to be a fairly easy task, and could be done to leave a completely clean area of ice. It was concluded from these experiments that burning is an effective method of removing small quantities of Prudhoe Bay crude.

It appears appropriate at this point to briefly discuss the information available for burning a special type of potential oil spill--that existing in the compartments of a wrecked tanker. An experimental test program

TABLE 4.4.

SUMMARY OF IN-SITU BURN TESTS (FROM THE WORK OF GLAESER AND VANCE, REF. 8)

Experiment	Wind Velocity, knots	Oil Spill: Volume, gal	Oil Spill: Average Thickness, inches	Oil Spill: Area, ft^2	Oil Spill: Approximate Diameter, ft	Time to Burn, min	Flame Height, ft	Burn Rate, gal/min
Fresh crude on water -no burning agents	10–14	32	.622	82.5	10.2	10	4–10	3.2
Fresh crude on water -fumed silica burning agent	6– 8	44	1.11	63.5	9.0	12	12	3.7
Fresh crude on ice -no burning agent	8	47	3.73	20.2	5.1	9	8	5.2
Aged crude on water (5 days)-no burning agent	0	55	1.22	72.5	9.6	12	12	4.6
Aged crude on water (6 days)-fumed silica burning agent	0	35	.681	82.5	10.2	8	12	4.4
Aged crude on water (6 days)-glass bead burning agent	0	44	.963	73.3	9.7	10	14	4.4
Straw on oil -aged 1 day	-	40	.401	160	19.3	13–14	-	3.0

Residue from all burns were approximately 2 to 10 percent of the original volume.

was performed in England by Diederichsen, et al.(9) concerning this problem as a direct result of lessons learned from the Torrey Canyon disaster (March, 1967). The particular lesson of the Torrey Canyon disaster was "that if all other methods of oil recovery prove impractical when a ship cannot be salvaged, and provided the location of the wreck permits, the cargo must be burnt . . .". Diederichsen, et al, extended earlier burn tests of crude oil in small tanks to larger tanks having dimensions 20 ft x 20 ft x 24 ft. They found that if certain conditions are met, it is possible to ignite and burn 97 percent of the oil contained in a compartment of a stranded oil tanker. The conditions are that vents be created in the top and in the windward side of each compartment, the areas being equal to 10 percent of the surface area of the oil. With an 11 m/sec wind and the side vent oriented upwind, a burn rate of about 240 mm/hr was obtained, while with no wind the value was about 100 mm/hr. Ignition was initiated by an incendiary device (chlorate tile). Therefore, in a tanker with compartments of 20 meter depth, burning would extend over a period of only 2 days with an 11 m/sec wind and about 5 days with no wind.

4.5.3 Wicking Materials for Burning Thin Oil Slicks

The data presented in Table 4-4 indicate that the crude oil burned very well under all conditions tested. However, examination of the data reveals that the oil spill thickness, without burning agents, were 0.622 inch, 3.73 inch, and 1.22 inch (Tests 1. 3, and 4). If the oil had been allowed to spread over a calm sea without wind or ice barriers, it is likely that it may have reached a thickness as small as 0.01 inch. Under this condition the thin oil film would probably not burn because the water cools the oil and slows its evaporation to the extent that combustion cannot be maintained. In fact, even when a slick is forcefully ignited (for example with the aid of flame throwers) combustion cannot be maintained; the fire quickly dies out. In the case of the Torrey Canyon disaster, the addition of thousands of gallons of aviation fuel and napalm combined with aerial bombing of the ship failed to produce any sustained burning. Therefore, it appears that some type of artificial burning aid is needed in this situation.

In response to this problem, research efforts have been conducted by several organizations to develop effective wicking materials. A research team from the Cabot Corporation has developed a wicking material, called CAB-O-SIL ST-2-0, which permits burning of very thin oil slicks on water[10]. They claim that,by using CAB-O-SIL ST-2-0 and the recommended treatment methods, 98 percent of spilled crude oil can be burned from the water surface. After burning, a nontacky, hardened residue, similar in appearance to tar paper, remains in a readily collectible form.

CAB-O-SIL ST-2-0 is composed of extremely fine particles of fumed silica surface-treated with a silane coating to render it hydrophobic. The material is nontoxic. The method of application consists of covering selected areas of the oil slick surface with a layer of the material by entraining the product in a stream of water which conveys it to the surface of the spill. As soon as the mixture strikes the oil, the water and the hydrophobic CAB-O-SIL ST-2-0 separate. The water sinks under the oil, if the oil is thin enough or has a low viscosity, and the CAB-O-SIL ST-2-0 rises to the top of it, forming a thick, foam-like coating. The treated area can then be ignited. Burning can be initiated with a piece of cloth which has been saturated with lighter fluid, then dropped onto the treated surface and ignited. The flame front travels gradually from the burning cloth to the treated area of the spill, and combustion is sustained until the oil in the immediate area of the CAB-O-SIL St-2-0 is consumed.

The action of the CAB-O-SIL ST-2-0 appears to be a specific example of the common wicking phenomenon. In this case, a layer of fine CAB-O-SIL ST-2-0 with tiny channels among the particles acts as the wick. As a wick, it increases the area of the oil-air interface, controlling the quantity of fuel in the heating zone and increasing the rate of evaporation of the oil. As the mass transport of oil from the liquid phase to the vapor phase is increased, sufficient vapor is formed to support combustion. The continued presence of a wick is essential to sustain combustion of a thin oil film. In addition, the wicking agent locally thickens the oil slick thereby reducing heat lost to the water. Fumed silica, having a high melting temperature, is unchanged at the temperatures of an oil fire. The need

for a wick to support combustion has another important aspect. Tests have indicated that the oil will burn where the CAB-O-SIL ST-2-0 is applied, and will not burn where no fumed silica exists, despite the heating of adjacent oil by the heat at the edge of the fire zone. The significance of this fact is that the size of the fire zone can be accurately controlled by limiting the initial spreading of the wicking material. The operational personnel, if so desiring, can burn off the oil zone by zone, always keeping the fire under control. Additionally, the fire can be quickly extinguished by standard water fog spray.

Figure 4-20 presents a diagram illustrating the mechanism of controlled combustion of oil spills on water as assisted by the CAB-O-SIL. As the fire burns, the oil directly beneath the flame and in an area extending slightly beyond the edge of the fumed silica blanket is warmed by the heat of the fire, reducing the viscosity of the oil. This reduction of viscosity accelerates burning once the fire gets underway, because oil of low viscosity wicks and volatilizes more rapidly. In addition, the elimination of oil by combustion produces a depression in the surface of the oil, creating a "hole" into which surrounding oil flows. The in-flowing of the oil towards the fire may preclude the need of applying the wicking material to the entire spill, permitting economical utilization of the material and simplifying the logistics of conveying the material to the scene. Another function of the wicking material is to serve as thermal insulation to promote oil heating by the flame by isolating oil in the wicking material from the cold water below.

Above the burning oil surface, the upward movement of the heated air induces flow of cold surface air toward the flame. The inward-flowing air fans adjacent vapors into the flame. This tends to centralize the fire and prevent spreading of the flames to the volatile oil vapors formed beyond the area of the immediate fire. Another action that Cabot believes to be in progress in the area of reduced viscosity, as indicated in Figure 4-20, is the evaporation of the imbibed water. Floating oil imbibes water over a period of time, further reducing combustibility. But the heated oil in the region of reduced viscosity evaporates contained water, increasing

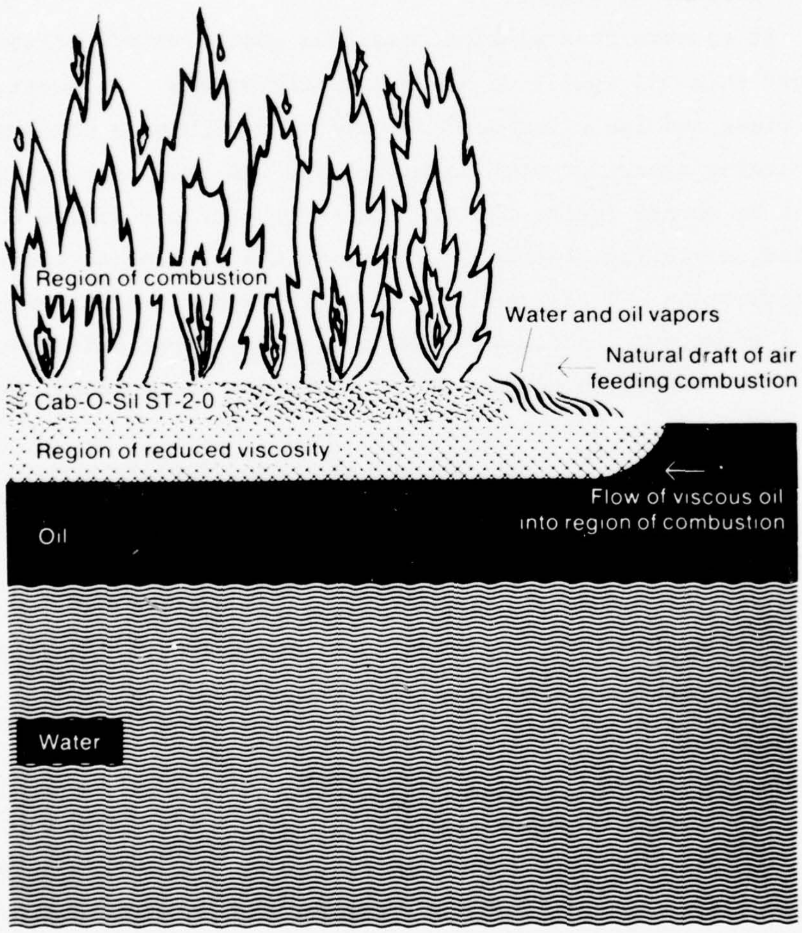

FIGURE 4-20. SCHEMATIC DRAWING OF THE CONTROLLED COMBUSTION PROCESS USING WICKING MATERIALS (from Reference 10).

the combustibility of the oil about to be burned. Laboratory work showed that burning with the assistance of fumed silica was effective with spills of any thickness down to about 2 millimeters ($\approx$0.06 inch). The quantity of CAB-O-SIL ST-2-0 required varied with the slick thickness, nature of the oil, and conditions of application. Recommended quantities are from 0.1 to 0.5 percent by weight.

It appears that wicking materials may be an effective aid for burning off thin oil spills on Alaskan marine waters. As mentioned previously, winds and ice often pool the oil to thicknesses which will burn without burning agents or wicking materials. In that case, it would be sufficient to merely ignite the oil. However, for oil spills in calm seas without ice, a wicking material may provide the wicking action needed to sustain combustion. It is recommended that further testing be conducted on wicking materials to determine the following characteristics.

(1) The usefulness in the low ambient temperature environment of the Arctic

(2) The maximum rate of oil disposal (gpm) as a function of material thickness, covered area, and oil characteristics

(3) The nature and quantity of residue after burning

(4) Appropriate packaging, transportation, and application methods for various size oil spills.

4.5.4 Clean In-Situ Oil Burning Techniques

The previous experiments indicate that the in-place, open burning of spilled oil (crude oil, fuel, or gasoline) is an effective method of removing the oil with a minimum of manpower and equipment under certain conditions. However, all the tests indicated that the oil burning produced "substantial black smoke". A thorough search of the combustion literature indicates that the only approach for reducing the smoke from open oil burning is to suppress the formation of the smoke with water sprays. The use of water sprayed over the surface of burning oil to suppress smoke has been

developed for the Naval Devices Training Center[11]. Experimental water-spray systems were installed in three fire-training simulators at the Norfolk Fleet Training Center and good control of smoke was demonstrated after a well-developed fire had been established. However, it proved impossible to light and develop an oil fire with the water sprays operating. In subsequent research by Hazard[12], a system for smokeless ignition of large oil fires was developed. This system was based on rapid injection and ignition of gasoline on the oil surface with water sprays operating, and similar systems are now being installed at a number of U.S. Navy firefighting schools. Figure 4-21 shows the general arrangement of a 15-foot fire tank which was tested at Battelle. As shown there, very light smoke is produced by the oil fire when adequate water is injected to suppress the smoke.

The Norfolk spray system has been in operation for three years under a variety of conditions including high winds and sub-freezing temperatures. However, the behavior of such a system under extremely cold arctic conditions has not been demonstrated. Use of a water-spray smoke-suppression system for a large arctic burn would require design of a system for controlled burning in a limited area, and provision of a means of supply of water in the ratio of about 1 lb water per lb oil burned. In addition, a means might have to be devised to keep the water from freezing in arctic temperatures as low as -50 F.

For cleanly burning oil spills in-situ on land or water, it may be possible to ignite the oil and to suppress the smoke by spraying the flame with water from rows of nozzles placed in the oil pool. The oil could be ignited using oil-soaked rags, throwing gasoline or JP 4 on the surface, or with some type of gas torch. To contain the burning area within the water-spray zone, it would be necessary, especially for large spills, to provide a pool separated from the main oil spill on land and to use some type of boom containment on water.

For pooling oil spills on land, it is necessary that the oil viscosity be low enough to permit the oil to flow easily, and that the oil has not been absorbed by the ice, snow, tundra, etc. A water-spray system, which would include a water pump and lengths of small pipe having spray nozzles at intervals, could be flown to the spill site and erected about

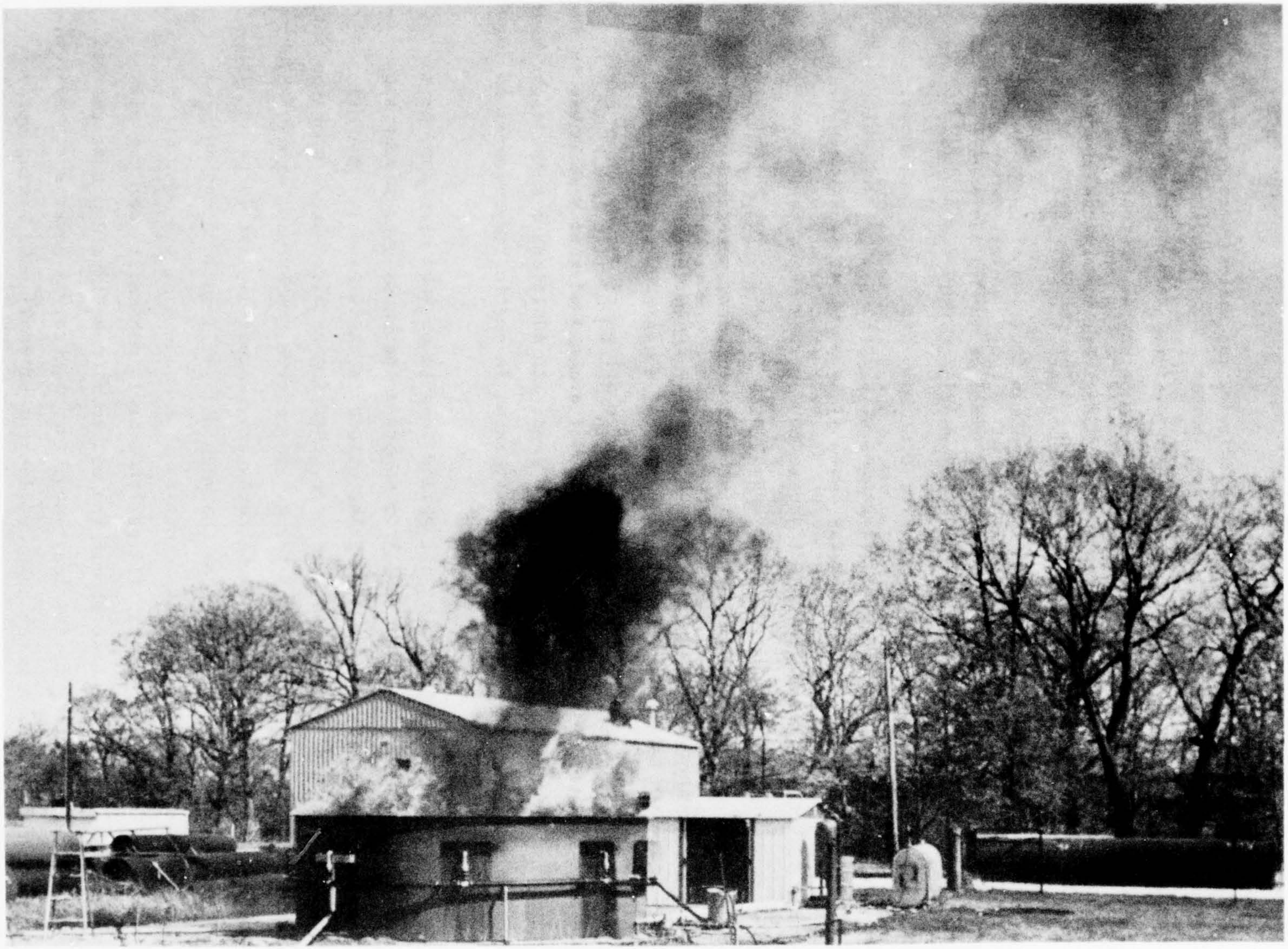

FIGURE 4-21. PHOTO OF AN OIL FIRE WITH WATER SPRAY SMOKE - SUPPRESSION EQUIPMENT DEVELOPED BY BATTELLE (Ref. 12)

or in the pooled oil. The oil from the large oil spill could be channeled (probably by digging) to the smaller burning pool, and burned with adequate smoke suppression. Figure 4-22 shows the general layout of such a system. This system, of course, depends on an adequate supply of water. For small spills remote from water, ice, or snow, it is conceivable that water could be flown in. However, if the spill was small enough that an adequate water supply could be flown in, it is probable that it could be burned off without smoke suppression equipment since the total amount of smoke generated would be small. For larger spills, it would be imperative that a supply of water be available locally. The heat from the burning oil would easily melt enough snow to provide the needed water if snow were heaped around the burning pool. The water would run to the bottom of the pool and could be pumped from there.

For oil spills on water, a floating spray-nozzle array could be enclosed by booms to contain the burning region. For thin oil slicks a wicking material might be needed. The booms, whether artificial or natural, would be required if the oil were thick enough to sustain widespread combustion while the wicking material would be required if the oil thickness was too thin to sustain combustion.

The booms could be the naturally occurring ice packs or artificial structures. In either case, the booms serve to contain the oil fire within the booms where water-spray nozzles are used for smoke suppression. Having enclosed the boom about a section of oil spill and having burned that section of oil, the boom could be opened and moved to enclose another section of oil until the entire oil spill was eliminated.

For spills that are too thin to sustain combustion, the wicking material could be sprayed over a local area of the spill, with the water-spray nozzles (possibly from ships) used to suppress the smoke in that local area. Ideally, the combustion process would proceed until the entire oil spill had been swept into the flame and burned. Thereafter, the remaining tar-like oil could be raked from the water surface and burned in small incinerators. It is recommended that boom-type devices and wicking materials be investigated, in combination with water-spray systems, for adequate smoke suppression of burning oil spills on water.

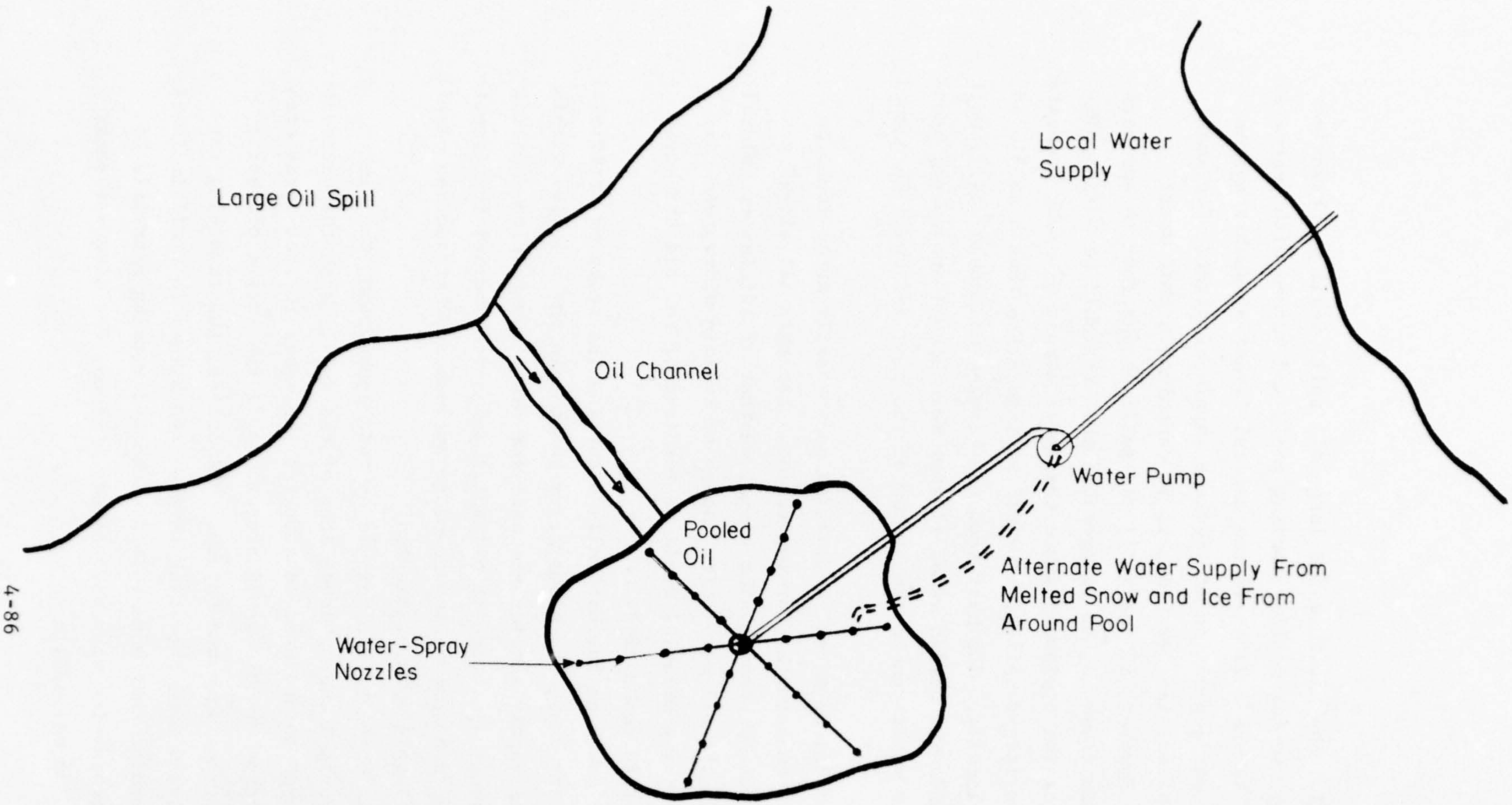

FIGURE 4-22. GENERAL LAYOUT OF A WATER-INJECTED, SMOKE SUPPRESSION SYSTEMS FOR IN-SITU OIL BURNING

4.5.5 Mobile In-Situ Oil Burners

If the oil temperature or aging has increased the oil viscosity to a semisolid, if the oil is in a thin slick on water, or if the oil has been absorbed by snow, ice, sand, etc., it may be possible to use a mobile burner, as shown in Figure 4-23 to burn the oil. The burner shown in this figure is equipped with pontoons for operation over water; however, these pontoons could be replaced with wheels or skids for operation on land, ice, or snow. A lightweight drag line would be used to pull the burner over the oil and debris to be burned. A small turbojet engine is mounted on the side of the burner to provide high temperature (about 1200 F) air to the combustion chamber. Air both for cooling and combustion is admitted through louvers near the bottom of the combustion chamber and through orifices near the top of the combustion zone. The burner could be designed with about an 8 ft diamter and a 10 to 12 ft height, utilizing sheet metal walls for the combustion shell. The height between the oil surface and the burner could be adjusted by adjusting the pontoons or wheels. This would provide for optimum burning under different conditions of temperature, fuel age, fuel thickness, etc. It is estimated that the "clean" burning rate for such a unit would be about 1 to 5 gallons per minute or between 1200 or 6000 gallons per day. Development testing is necessary to determine whether a water-spray system is required to suppress smoke formation. If required, a portable pump could be mounted outside the combustion shell to supply water to a water ring installed above the flame zone.

Since oil on water would be in a liquid state, it is possible that oil-on-water combustion could be sustained within the combustion chamber without supplementary hot vitriated air after ignition was obtained. Ignition might even be obtained by merely throwing lighted oil-soaked rags into the burner or perhaps using a portable gas torch burner mounted inside the combustion zone. This type burner could be designed having a natural draft chimney to induce an inward flow of air beneath the burner to sustain combustion. This inward flow of air beneath the burner might also move oil

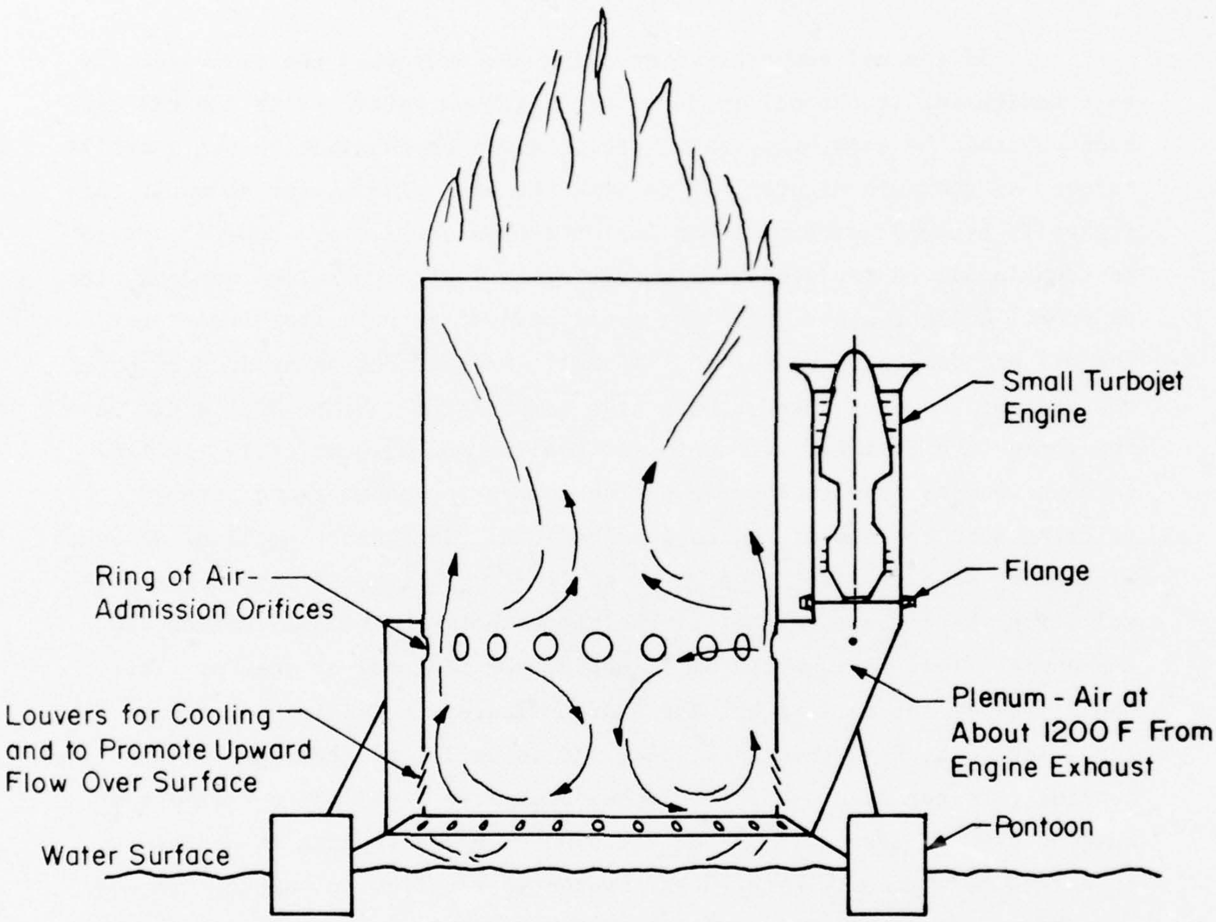

FIGURE 4-23. MOBILE OIL BURNER UTILIZING JET ENGINE EXHAUST FOR OIL IGNITION AND VAPORIZATION

inward with it, burning oil from an area considerably larger than that covered by the burner. Consequently, the burner could be left in place and a small oil pool could be swept into the burning zone due to the generated currents. This type of natural draft burner for sea oil spills was proposed by A. A. Putnam of Battelle-Columbus in 1969[13]. Another possible approach might be to use a wicking method (such as CAB-O-SIL ST-2-0) to supply oil to the stationary burner.

Development and testing may indicate that relatively smoke-free combustion can be obtained without water sprays. This may be possible if the draft chimney is designed to bring in air and the surface oil in the correct ratio for good combustion. In addition, the inflow velocity of air and surface oil must be high enough to keep the fire contained within the burner.

It appears that the mobile burner shown in Figure 4-23 could be used with minor modifications to dispose of spilled oil in practically any form and in most locations. The oil disposal rate would depend on many factors including the size of the burner combustion area, the delivered rate of hot air, the oil spill volatile content, the thickness of the spilled oil, and the amount of ice, snow, or debris mixed with the oil. For small or medium size spills, one or several of these burners could be employed whereas for the largest spills, a fleet might be needed. However, the size, weight, and cost of such burners should be relatively low; and they should be air transportable quite easily using fixed wing aircraft and/or helicopters.

Although the mobile-burner concepts described above have not been translated into hardware, it is proposed that this type burner be given special attention for disposing of arctic oil spills. A research and development program should be undertaken to determine the design characteristics of such burners for handling the full range of oil spill sizes, both with and without water spray smoke suppression capability.

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4.6 PRESENT CAPABILITY IN ALASKA FOR STORAGE AND DISPOSAL OF RECOVERED OIL

The use of existing facilities for temporary storage and/or ultimate disposal of oil recovered from the representative sites investigated in this study is assumed to be limited to facilities in the immediate vicinity of the spill site, except in the cases where the recovered product has a substantial value or equipment that can be brought to the site within 24 hours. Storage facilities would be either permanent or portable and fall into the following categories:

- fixed storage tanks
- portable storage tanks (pillow tanks, swimming pools, etc.)
- ships
- barges

Disposal facilities could be either in the immediate vicinity or up to hundreds of miles distance according to the value of the product. Existing disposal facilities would include the following:

- municipal incinerators
- municipal dumps or sanitary waste disposal sites
- refineries (for reprocessing)
- fuel suppliers (for reuse)

There are few potential advantages to transferring recovered petroleum products from the spill site unless the operation is cost-effective. The normally great distances, attendant logistics, and danger of a secondary spill make virtually all secondary transfer operations inefficient unless the product has a significant value for reuse. The only petroleum products considered within the present study that can have a significant value following recovery are gasoline and distillate fuel oil. The handling and transfer of gasoline entails such a potential safety hazard in field operations that transfer for reuse is not considered a feasible alternative. Distillate fuel oil can be handled safely and reuse is a distinct possibility, depending upon the condition

of the recovered product. The reuse of recovered crude oil by refining or direct utilization such as in road-oiling operations will seldom be feasible because only one small refinery presently exists in Alaska (Cook Inlet). Certain instances of major spills involving lighter petroleum products where the product was contained immediately and not emulsified could be handled by transferring the product directly to an oil tanker for transport to suitable facilities outside Alaska. However, the probability of an oil tanker's being available nearby and further being able to approach the spill site in the normally shallow coastal waters is considered very remote.

4.6.1 Storage

Fixed storage tanks for various types of fuel exist at all military bases, municipalities, and sites of industrial processing such as fish processing plants and fueling docks. The use of these storage tanks for storage of petroleum products recovered from spills would have to be considered on a case-by-case basis and would normally be restricted to volumes of less than 1,000 barrels. Military facilities within Alaska having large storage tanks are tabulated below:[1]

Location	Total Storage Capacity (Thousands of Barrels)
Elmendorf Air Force Base	352
Eielson Air Force Base	665
King Salmon Air Force Facilities	122
Galena Air Force Facilities	103
Shemya Air Force Base	256
Fort Richardson (Army)	16
Fort Wainwright (Army)	?
Fort Greeley (Army)	37
Kodiak Coast Guard Base	205
Adak Naval Station	157
Anchorage Terminal	321

Whittier Terminal	265
Fairbanks Terminal	188
Tok Terminal	272
Haines Terminal	372

Fuel barges are common throughout Alaska, particularly in Cook Inlet and coastal cities along the Bering Sea such as Nome and the King Salmon area. The tank barges have capacities up to 7,000 barrels which would provide storage for spills up to the intermediate range, 1,000 to 10,000 barrels. The largest spill considered in the present study (50,000 barrels) would require approximately ten large barges for storage when excess provision for emulsified or trapped water is considered. The possibility of obtaining ten of these vessels at a particular site within a few days' period is considered to be very remote.

Ships with a potential for temporary storage of small quantities (approximately 100 barrels) of oil are located in virtually all areas of the Gulf of Alaska and Bristol Bay. The only large vessels in the state capable of storing larger quantities (up to 1,000 barrels) are Coast Guard cutters and oil tankers. The feasibility of directly using vessel fuel tanks for storage of products that have been released and subsequently recovered is questionable in most instances due to transfer problems and the resultant contamination. The use of ships of opportunity is, therefore, felt primarily restricted to the provision of working platforms to support portable storage tanks. An exception is the use of tankers, etc., to receive products transferred directly from a clean source such as a strickened vessel. An example would be unloading directly into a tanker by the ADAPTS system developed by the Coast Guard.

4.6.2 Disposal

Ultimate disposal in an economically viable manner by reuse or reprocessing is felt highly unlikely in Alaska. Large spills of crude oil or distillate fuel oil exceeding 10,000 barrels could be reused or

reprocessed if the spills occured in Cook Inlet or Prince William Sound. The Army has laboratories at Fort Richardson at which recovered petroleum products can be analyzed and reblended for subsequent reuse. However, the recovered product is unacceptable if exposed to seawater. The ballast treatment facilities being installed at the Trans-Alaska pipeline terminal at Valdez may eventually provide a source of disposal for virtually unlimited quantities of all types of recovered products that can be handled by the separators. The feasibility of such an approach would have to be explored with the oil companies. Transfer of products over long distances (exceeding a few hundred miles) to the Valdez facilities is not felt to be cost-effective under any circumstances.

Disposal of small quantities (up to 100 barrels) of recovered petroleum and oil-soaked debris could be effected at local dumpsites that were directly accessible from the spill site. The very limited populations in coastal towns (generally well under 3,000 people) indicate that such dumpsites would have very limited capacity. Disposal of petroleum products in a fluid state at dumpsites is not recommended at any location within Alaska due to the likelihood of secondary contamination. Landfill disposal of quantities greater than 100 barrels would be limited to large metropolitan areas such as Anchorage and Fairbanks and the larger military bases near the same cities.

4.6 REFERENCES CITED

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5.0 EVALUATION OF STORAGE AND DISPOSAL METHODS AT SELECTED SITES

The choice of a few sites within Alaska that reflects the range of physiographic and environmental conditions which will be encountered in future oil spill recovery and disposal operations is difficult. Areas of the coastline and mainland of the state potentially threatened by oil spills will approach ubiquity in the future, if all promising geologic formations underlying the onshore and continental shelf areas are developed. Areas of high oil spill potential were identified in a previous study for the Coast Guard by Battelle-Northwest(1) based on the occurrence of promising geologic formations and most probable transportation routes. A follow-on study by Battelle-Northwest(2) identified the logistic response requirements and evaluated capabilities for response to oil pollution incidents at fourteen selected sites of high potential within Alaska. The fourteen sites selected for that study were:

Offshore Yakutat	Offshore Nome
Valdez Narrows	Offshore Cape Blossom
Offshore Port Graham	Offshore Prudhoe Bay
Drift River Terminal	Onshore Prudhoe Bay
Unimak Pass	Umiat
Offshore Port Moller	Yukon River pipeline crossing
Kvichak Bay	Denali Fault pipeline crossing

The seven sites selected for evaluation in the present study were chosen from locations of high spill potential tabulated above and are as follows:

Offshore Yakutat
Lower Cook Inlet (Kachemak Bay)
Unimak Pass
Kvichak Bay
Umiat
Offshore Nome
Offshore Prudhoe Bay

Factors affecting the transfer, storage and disposal of oil recovered from spills include the geographical and environmental setting, ecological hazards, amount and type of debris present (including snow and ice), type of petroleum product and degree of weathering, terrain and soil conditions, oceanographic and climatological conditions, accessibility, and proximity or access to useful equipment, facilities and personnel. The sites selected are felt to fairly represent typical ranges of the most significant factors. The representative sites are dispersed geographically which is important from the standpoint of logistics. The offshore setting of most spill locations is based on the fact that up to 70% of Alaskan crude oil production may emanate from offshore fields[1]. Marine spills are of immediate concern to the Coast Guard because such spills fall in the area of direct responsibility under the Federal Water Pollution Control Act. A further rationale used in the selection of representative sites was the fact that spills in remote areas and along transportation routes are much more likely to require direct Coast Guard participation in cleanup and disposal operations. Provisions for cleanup and disposal of oil spills in the immediate areas of petroleum production and transfer facilities must be provided by private industry. Thus, production fields such as onshore Prudhoe Bay and the Trans-Alaska Pipeline System transfer terminal at Valdez will presumably have the required equipment and facilities to recover and dispose of spills. Similarly, metropolitan areas such as Anchorage and Juneau have or will have the required cleanup and disposal capability.

The seven sites selected for evaluation of methods for storage and disposal are characterized in the following subsections. Attention has been given to the types and abundance of waterfowl in each area because of the great numbers of indigenous and migratory birds found throughout the state. The birds are important from two aspects:
(1) they constitute debris when floating dead on the water and (2) the ecological threat of oil spills or subsequent release of stored oil is the greatest to birds at virtually every location of high oil spill probability.

Natural disasters to birds are frequently recorded and the pressures of man upon survival can be equally severe. A few recent events which indicate the potential magnitude of deaths to birds include:[3]

- An estimated 100,000 eider ducks died from starvation along the Beaufort Sea during the cold spring of 1964.
- An estimated 86,000 common murres washed ashore following a severe storm in Bristol Bay in 1970.
- At least 100,000 birds, mostly alcids and waterfowl died from oil pollution around Kodiak Island in 1970. The source of the oil is believed to have been ballast dumped from tankers entering Cook Inlet.

Each of the seven sites selected above is assessed in terms of the feasibility of alternative approaches to storage and disposal over a range of spill sizes (100, 1,000, 10,000 and 50,000 barrels) and types of product spills (crude oil, distillate fuel oil, residual fuel oil and gasoline). The assessment of feasibility is based upon subjective judgment in many types and sizes of spills due to uncertainties in the condition of the spill to be handled (i.e., engineering properties, degree of weathering, debris present, etc.). Certain assumptions were necessary to permit a comparative evaluation of approaches at each of the selected sites which are tabulated below. The possible constraints due to debris are evaluated separately for each separate site on a seasonal basis. The assumptions made regarding the factors which most seriously affect transfer, storage and disposal operations are as follows:

1. Environmental extremes such as heavy seas, high winds, and extreme cold do not exist during the first days of the operation. Such extremes will exist during subsequent storage.
2. In situ burning is possible with gasoline, distillate fuel oil, and crude oil in the case of both marine spills and onshore spills. The extreme potential hazard relating to operations involving the burning of gasoline in situ would limit such practices to the larger spills that seriously threaten the local ecology. Smaller spills would be left to evaporate

or otherwise dissipate. It is further assumed that safe procedures are available for remote ignition of gasoline spills (aerial bombardment).

3. Storage capacity for temporary containers will require an excess capacity of 50%.

4. Immediate storage is defined as either natural features such as small lakes, ice barriers or man-made devices which are already available at the immediate spill site or within a few nautical miles of a marine spill. A further requirement for immediate storage is that suitable docking and transfer facilities are existing.

5. Temporary storage in portable containers is considered only where suitable onshore access is available. No type of floating storage tank that is filled at the site and towed elsewhere (more than a few nautical miles) or left moored at the site for extended periods is felt feasible.

6. Controlled burning is feasible only where access to the shoreline or immediate spill area exists. Rocky coastlines without beaches or areas in which heavy surf can be expected will not permit controlled burning operations.

7. Landfill is feasible only where existing dumpsites are established. The limit for existing dumpsites with respect to spill sizes is based on the availability and size of towns in the immediate spill area, Other forms of land disposal such as controlled spreading over large areas are not feasible in the arctic and sub-arctic environment.

8. Reprocessing or reuse of recovered oil is feasible only when the spill occurs in the areas of Cook Inlet accessible by road and near Valdez where ballast treatment facilities will be available.

9. Field operations requiring travel overland or by water for distances greater than 20 nautical miles (i.e., from the spill to a storage site, etc.) will be assumed ineffective due to logistic constraints.

10. Transfer of recovered oil off-site is possible only after the recovered oil has been stored in portable containers near suitable docking facilities. Transfer is feasible only by vessels or land vehicles.

11. Temporary storage is defined as storage in portable containers or existing tanks for periods up to one year.

Each of the seven sites selected is briefly characterized from an environmental standpoint in the following sections. A comparative evaluation of the approaches to storage and disposal of recovered oil is then presented in matrix form for the range of spill types and sizes. The matrix evaluation is a general comparison of all areas based directly on the assumptions tabulated above. Further discussions regarding the comparative feasibility of the possible approaches for each site follows the tabular presentation.

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5.1 OFFSHORE YAKUTAT

5.1.1 Shoreline Characteristics

The Yakutat Bay area has a variety of coastal characteristics consisting of tidal flats, sand beaches, river and glacial deposits, marshes, bluffs, ice, and natural vegetation. One of the most prominent coastal features is the tremendous Malaspina Glacier which comprises the northwest shore of Yakutat Bay. Here the coast is largely river and glacial deposit, ice cliffs, and bluffs (Sitkagi Bluffs).

The southeast side of the Bay consists of islands (Khantaak, Haenke), tidal flats, sand beaches, bluffs and trees, bushes and grass. The town of Yakutat is located in the eastern end of Monti Bay.

The coastline of the Gulf of Alaska southeast of Yakutat Bay consists primarily of tidal flats and sand beaches with some areas of river and glacial deposit and marshes. The southeast portion of the Yakutat Bay area is located in the Tongass National Forest. Figure 5.1 shows the geographical features of Yakutat Bay and surroundings.

5.1.2 Oceanographic Conditions

Tide Ranges

The southeastern coast of Alaska experiences very large tide ranges. At Yakutat the diurnal range of tide is 10.1 feet. Mean lower low water at Yakutat is based on six years of record (1954-59) reduced to mean values. Elevations of other tide planes referred to this datum are given in Table 5.1.

TABLE 5-1

TIDAL RANGES FOR YAKUTAT BAY

	Feet
Highest tide observed (November 2, 1948	14.90
Mean higher high water	10.10
Mean high water	9.20
Mean tide level	5.30
Mean low water	1.40
Mean lower low water	0.00
Lowest tide observed (December 29, 1951 and January 16, 1957)	-3.90

Source: U.S. Coast and Geodetic Survey, Anchorage, Alaska.

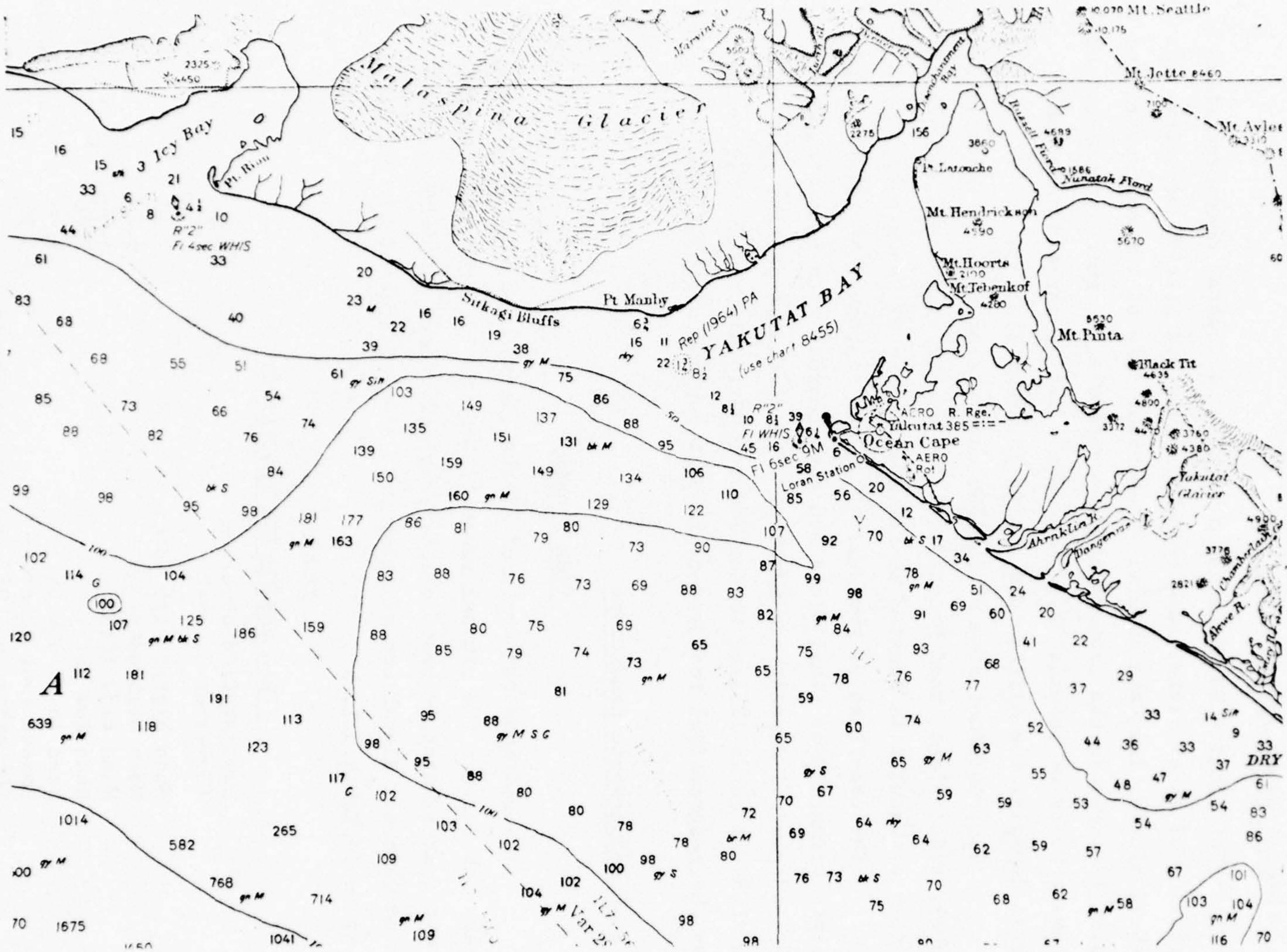

FIGURE 5-1. OFFSHORE YAKUTAT (from C.&G.S. Chart 8002)

Currents

In the Gulf of Alaska, the general surface flow is the result of the large oceanic eddy (Alaskan gyre) which is formed by the Alaskan current as it flows north and west along the southeastern coast. The velocity of current in the Yakutat area is commonly between 1.5 and 2 knots. This current, along with periodic onshore winds, tends to drive waterborne materials on the sea surface onto the shore at a speed of about 3 to 5% of the wind velocity.[1]

The limited fetch available to the intense local storms results in the generation of steep short-period waves. Major long-period waves only occasionally come to the Yakutat area; breakers are then observed along a submerged moraine at the mouth of the bay.[2] During severe weather breakers or pronounced increased height of swell has been observed to occur across the entire entrance to Yakutat Bay; at such times entrance is dangerous.[3]

Ice

Sea ice does not form in Yakutat Bay, but large quantities of small icebergs are produced by the Hubbard and Turner Glaciers, at the head of Disenchantment Bay. These small bergs are generally found only in the northern part of Yakutat Bay, around Blizhni Point but occasional drifters find their way as far south as Ocean Cape and Point Manby at the mouth of the bay.[2] [3]

5.1.3 Climatology

General Climate

The Yakutat Bay area has a maritime-alpine climatic regime typical of the southeastern Alaska coast. This climate is influenced by the relatively warm Alaska current that flows northwestward along the coast, the extensive ice fields of the nearby Chugach and St. Elias Mountains and the frequent cyclonic storms in the Gulf of Alaska. During spring, fall, and winter months the Yakutat area is subjected to numerous storms, usually accompanied by extensive cloudiness, rain or snow and high winds.

Significant Weather Elements

Snow - Snow has occurred in all months of the year except June, July, and August. The seasonal snowfall (Sept. to May) has varied from 121 to 338 inches since 1948. Table 5.2 shows the maximum snowfall that has occurred in 24 hours and the mean number of days snowfall has exceeded 1 inch or more at the observation site in Yakutat.

TABLE 5-2

SNOWFALL STATISTICS FOR YAKUTAT

J	F	M	A	M	J	J	A	S	O	N	D
Maximum in 24 hrs (inches)											
23.5	20.7	32.4	18.1	10.0	0	0	0	T	14.7	17.3	23.1
Mean number of days snowfall one inch or more											
9	10	9	5	1	0	0	0	0	2	5	10

Wind - The prevailing wind direction is from the east and east-southeast with mean monthly wind speeds varying from 6 to 9 knots. Fastest observed 1-minute speeds have varied from 30 knots to 65 knots and have been from the southeast sector.

Katabatic winds or down-slope cold air drainage results in strong winds and can cause wide variations of temperature within short distances. Table 5.3 shows the percentage frequency of wind speeds equal or greater than 17 knots and 28 knots, respectively.(4) Strongest winds occur during the winter months.

TABLE 5-3

PERCENTAGE FREQUENCY OF STRONG WINDS AT YAKUTAT

J	F	M	A	M	J	J	A	S	O	N	D
% Frequency wind speed $\geq$ 17 knots											
14.8	10.1	11.3	6.7	4.3	2.7	2.7	4.3	5.4	11.9	11.3	12.9
% Frequency wind speed $\geq$ 28 knots											
3.2	1.5	1.5	0.9	0.6	0.1	0.1	0.2	1.0	1.8	2.1	2.2

Temperature - Mean annual temperature of Yakutat is 39°F, however, on a year-to-year basis it has varied from 35°F to 41°F. Table 5-4 shows the extreme temperature for each month at Yakutat(5) and Table 5-5 presents the mean number of days when temperatures are 32°F and below and 0°F and below.

TABLE 5-4

EXTREME TEMPERATURES AT YAKUTAT

J	F	M	A	M	J	J	A	S	O	N	D
Absolute maximum temperature °F											
49	56	55	66	80	79	84	86	77	62	59	52
Absolute minimum temperature °F											
-22*	-19	-13	3	9	30	36	30	25	12	-10	-15

* -24°F has been recorded in the area.

TABLE 5-5

MONTHLY VARIATION IN FREEZING TEMPERATURES AT YAKUTAT

J	F	M	A	M	J	J	A	S	O	N	D
Mean number of days maximum temperature 32°F and below											
23	12	6	0.5	0	0	0	0	0	1	7	17
Mean number of days minimum temperature 32°F and below											
30	27	28	27	13	1	0	1	5	15	24	28
Mean number of days minimum temperature 0°F and below											
10	4	2	0	0	0	0	0	0	0	1	4

Both daily and seasonal average temperatures are held within fairly well-confined limits. Differences between average maximum and minimum readings range from over 12° in October to about 16° in April and May. Normal monthly temperatures range from about 26° in January to around 53° in July and August. The record low has been -24° and an average of approximately 20 days occur each year with temperatures below zero.(5)

5.1.4 Biota Distribution

Avifauna

There have been no detailed waterfowl surveys conducted in this local area, even though thousands of migrating birds use the immediate tidal zone habitat in spring and fall. Peak numbers of migrating birds occur during mid-April and mid-October. Most waterfowl use occurs from tideline to about 400 ft elevation.

Casual observations[6] during the fall in the Yakutat area indicate peak Canada goose populations over 10,000, snow geese - 10,000, swans - 3,000+, sandhill cranes - several thousand, ducks - thousands, and shore birds - millions. Wintering mallards, Canada geese, some divers and sea ducks occur in unknown numbers where open water with suitable food is present. Trumpeter swans have also been observed during the winter.

Primary waterfowl habitat is associated with intertidal and estuarine areas and is therefore susceptible to oil pollution. Key waterfowl habitat areas are Akwe River Drainage, Dangerous River Drainage, Dry Bay and Situk River Drainage. There are fourteen species of waterfowl breeding in this area. A seabird colony is also located on the Yakutat Bay Islands where glaucous-winged gull, pigeon guillemot and black-legged kittiwake reside.

Tremendous numbers of waterfowl follow the coastal migration route, encompassing inshore and tidal areas and to some extent the edges of the land corridor. These migrants parallel the eastern North Gulf Coast west to the Copper River Delta, where some migrants continue along the outer coast, bound for breeding areas in adjacent western Alaska, but where most move into and across Prince William Sound.[7]

Marine Mammals[6]

Harbor Seal - Harbor seals are very abundant in areas of Yakutat Bay, Icy Bay, Dangerous Bay and Dry Bay. Population estimates are not available but the area had produced an annual harvest of 4,000 to 6,000 seals during the 1960's. They are present in all coastal waters.

Sea Otters - Small numbers of sea otters have been sighted throughout the area. Total numbers are unknown but it is believed that the population is increasing.

Sea Lions - Sea lions have a rookerie and hauling ground at Sitkagi Bluffs. The latest population estimate from this site indicated 1,000 sea lions.[8] They are present in all coastal water.

Other - Dall and Harbor porpoises and whales are commonly seen in the offshore waters. Gray whales pass through on their annual migration.

Fish

There is a commercial salmon fishery at Yakutat but the fishing district is considered minor compared to others in the Gulf of Alaska. The average salmon catch (all types) in the Yakutat district during the years 1960-1968 was approximately 265,783. There are a number of spawning grounds for different types of salmon in the head waters of Yakutat Bay and in some coastal rivers in the Yakutat district.[9]

Kelp

Extensive kelp beds are located off Ocean Cape, in Monti Bay and around Khantaak Island and Krutoi Island.

Driftwood

Discussions with forest service personnel[10] in Juneau indicate that driftwood is transported by the Alaska current and onshore winds eventually ground this material along the coastline of the Gulf of Alaska southeast of Yakutat Bay. However, detailed information concerning the density of driftwood along the coastal areas surrounding Yakutat could not be found. Onsite inspection is probably required.

5.1.5 Evaluation of Approaches to Storage and Disposal of Recovered Oil Offshore Yakutat

Marine spills in the Gulf of Alaska offshore of the Yakutat area will likely occur elsewhere and arrive in a weathered condition. The exposed nature of the area will normally preclude the use of small vessels working in the open ocean. Large vessels suitable for recovery on the ocean are unlikely to be available locally and will require a day or more to reach the scene from elsewhere. Spills that reach the ocean beaches can be worked from the low, flat shoreline south of Ocean Cape. However, the established road system along the coastline is extremely limited and the coastal area is cut by rivers, which would prevent transfer of recovered oil to a consolidated storage site near the town of Yakutat where the only adequate docking facilities exist. Oil spills that entered or occurred in Yakutat Bay or were recovered on the high seas and transported within the bay could readily be handled and stored in portable containers for subsequent disposal by incineration. Table 5-6 is an estimate of the feasibility of various approaches to storage and disposal of recovered oil from a range of spill sizes and types based upon present technology.

The remoteness and light industrial development in the Yakutat area precludes direct use of recovered products or efficient transfer out of the area for reprocessing or use elsewhere. The use of local dumps (primarily at the town of Yakutat) for land disposal of recovered petroleum products would be limited to very small quantities, (<100 bbls), based on the assumption that any dump site established for a town of a few hundred people cannot cope with larger quantities of oil. It is also felt that gasoline or distillate fuel oil should never be disposed at a small dump from a safety standpoint.

In situ burning of the oil at sea or along the shoreline is clearly the preferred method of disposal if it can be accomplished safely due to the remoteness and attendant logistics problems in the area offshore from Yakutat. Gasoline should be left to dissipate naturally unless a threat of serious ecological damage occurs. Oil spills reaching shorelines would preferably

TABLE 5- 6

EVALUATION OF APPROACHES TO STORAGE AND DISPOSAL ALTERNATIVES AT OFFSHORE YAKUTAT

Type of Product And Spill Size	In situ Burning		Immediate Storage Available		Temporary Storage In Portable Containers		Controlled Burning		Incineration		Landfill		Reprocess or use Directly		Transfer Off-Site	
	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
CRUDE OIL																
100 barrels	X		X		X		X		X		X			X		X
1,000 barrels	X			X	X		X		X			X		X		X
10,000 barrels	X			X	X			X	X			X		X		X
50,000 barrels	X			X		X		X		X		X		X		X
RESIDUAL FUEL OIL																
100 barrels		X	X		X		X		X		X			X		X
1,000 barrels		X		X	X		X		X			X		X		X
10,000 barrels		X		X	X		X		X			X		X		X
50,000 barrels		X		X		X	X			X		X		X		X
DISTILLATE FUEL OIL																
100 barrels	X		X		X		X		X			X		X		X
1,000 barrels	X			X	X		X		X			X		X		X
10,000 barrels	X			X	X			X	X			X		X		X
50,000 barrels	X			X		X		X	X			X		X		X
GASOLINE																
100 barrels	X			X		X		X		X		X		X		X
1,000 barrels	X			X		X		X		X		X		X		X
10,000 barrels	X			X		X		X		X		X		X		X
50,000 barrels	X			X		X		X		X		X		X		X

be burned in situ or by controlled burning processes at the immediate site because of the difficult logistics associated with transfer and transport in the area. Temporary storage in pillow tanks or other portable containers erected in the immediate shoreline area would be required in the event that the recovered oil could not be burned in situ or under controlled conditions. However, subsequent disposal by incineration would probably require airlift of the incinerators to the site by helicopter, thus limiting the size of the incinerator(s).

The terrain and availability of readily accessible land around the town of Yakutat would pose no problems to temporary storage in portable containers and subsequent disposal by incineration. There is no permafrost in the area and local equipment would be available to construct secondary containment dikes around the storage area. However, practical considerations regarding the logistics of large spills and local unavailability of equipment are felt to limit the probability of transporting recovered oil to the town essentially to those spills which enter Yakutat Bay.

The immediate storage of quantities of recovered oil up to 100 barrels is an estimate based on the fact that the fuel tanks or holds of fishing vessels or other ships in the area could be used in the event of an emergency oil response situation. An upper limit of 10,000 barrels storage capacity was estimated for tempory storage containers based on the high cost and large number required to store 50,000 barrels (including 50% excess capacity to accommodate entrained water).

Debris in the Yakutat area would not be severe in most cases. Snow and ice would be limited or nonexistent. Driftwood exists on the shorelines exposed to the ocean. Dead birds would constitute the greatest potential debris handling problem for offshore spills. All debris collected in offshore spills could presumably be handled in portable totes lashed to the decks of vessels. Subsequent disposal could be either by stacking and burning, disposal at the local dump (for small quantities), or eventual incineration.

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10. Personal communication, Mr. Marcus Petty, USFS, Anchorage, Alaska.

5.2 LOWER COOK INLET (KACHEMAK BAY)

5.2.1 Shoreline Characteristics

Kachemak Bay, in the lower Cook Inlet, has a variety of coastal characteristics consisting of tidal flats, marshes, steep bluffs and cliffs, coastal forest, glacial deposit and gravel spits. A prominent feature of the bay is the Homer spit, a low gravel and shingle spit covered with grass and some trees. It is about 4 miles long and from 100 to 500 yards wide. Extensive use is made of the spit by fisheries, tourists and residents.

The south side of the Bay is very irregular consisting of numerous coves and bays, rocky outcroppings and forest. A glacial deposit is at the head of Grewingk Glacier. In contrast, the north side of the bay is lower and consists of tidal (mud) flats backed by bluffs and higher wooded terrain. The head of the Bay where the Fox River empties consists of extensive marshes. The coast between Homer and Anchor Point is a line of bluffs with the greatest height of 750 ft. at Bluff Point. In front of the bluff is a narrow rock and shingle beach. Marshes are located in back of the bluffs. Figure 5-2 shows the geographical features of Kachemak Bay.

5.2.2 Oceanographic Conditions

Tide Ranges

Cook Inlet is noted for its extreme tide range. At Anchor Point, the diurnal range of tide is 18.7 feet and at Seldovia it is 17.8 feet. Table 5-7 gives the elevation of other tide planes for Anchor Point and Seldovia.

TABLE 5-7

TIDAL RANGES FOR KACHEMAK BAY

	Anchor Point (ft)	Seldovia (ft)
Highest Tide	25.0 (estimated)	23.0
Mean Higher High Water	18.7	17.8
Mean High Water	18.0	17.0
Mean Tide Level	9.9	9.3
Mean Low Water	1.8	1.6
Mean Lower Low Water	0.0	0.0
Lowest Tide	-6.0 (estimated)	-5.5
Mean Range	-	15.4
Extreme Range	-	28.5

Source - U.S. Coast and Geodetic Survey, Anchorage, Alaska.

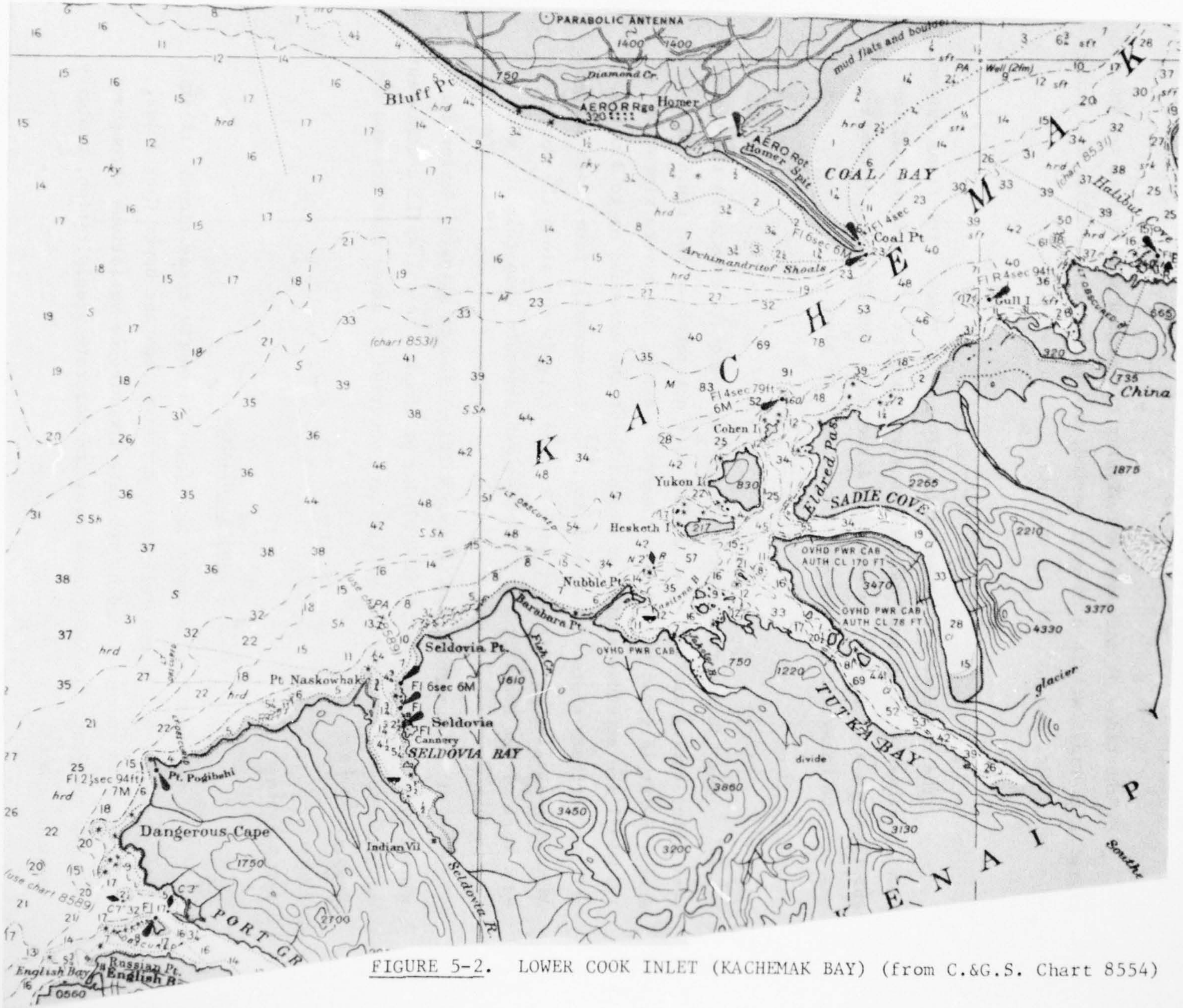

FIGURE 5-2. LOWER COOK INLET (KACHEMAK BAY) (from C.&G.S. Chart 8554)

The tides of Kachemak Bay display the common semidiurnal tendency of two high tides within a 24-hour period, one generally exceeding the other by several feet and the same is true for the two low tides.

Currents

The currents are governed largely by the tides. The flood current flows northeasterly up Kachemak Bay at a velocity of 1 to 2 knots and the ebb flows in a sourthwest to westerly direction. Currents at the mouth of the bay are uncertain and may vary from place to place.

Ice

Sea ice and the other types of ice are quite common in the Upper Cook Inlet during winter. Ice usually does not reach as far south as Anchor Point in great quantities. However, during the severe winter of 1970-1971 ice extended as far as Anchor Point and extended up to 3 miles off the northern shore of Kachemak Bay.(1) Ice normally forms each winter along the shallow mud flats of Coal Bay and extends out along the Northeast side of the Homer Spit. The tides and currents keep this ice well broken.

Ice frequently causes some difficulties to shipping during the winter season and ice would also hinder or complicate oil spill containment and cleanup but to date oil spills have occurred at times when ice was not present.(1)

5.2.3 Climatology

General Climate

Kachemak Bay on lower Cook Inlet is in the transitional climatic zone of Alaska but is generally more maritime than the upper Cook Inlet. The region is characterized by moderate temperature variations throughout the day and year, frequent cloudiness and moderate precipitation, humidity, and wind speeds.

Significant Weather Elements

Snow -- snowfall has occurred in all months of the year except July and August. The seasonal snowfall (Sept. - June) has varied from 31 in. to 98 in. during the past 30 years. The maximum snowfall in 24 hrs and the mean number of days snowfall has exceeded one inch or more is presented in Table 5-8 for Homer.

TABLE 5-8

SNOWFALL STATISTICS FOR HOMER

J	F	M	A	M	J	J	A	S	O	N	D
Maximum snowfall in 24 hrs (in.)											
24.0	19.2	15.2	7.4	6.0	T	0	0	0.4	6.0	24.5	14.0
Mean number of days with snowfall one inch or more											
3	5	4	3	1	0	0	0	0	1	2	4

Wind - The prevailing wind direction is northeasterly from September through May and west-southwest from June through August. The monthly mean speeds vary from 4 knots to 6.5 knots and are stronger during the winter months. The fastest one-minute speeds have varied from 17 knots to 30 knots with the stronger speeds from the east sectors. However, the wind speeds at Homer may not be typical for the whole bay. Wind speeds of greater velocities have been reported in the western portions of the bay.[1]

Table 5-9 shows the percentage frequency of windspeeds equal or greater than 17 knots and 28 knots at Homer.[2]

TABLE 5-9

PERCENTAGE FREQUENCY OF STRONG WINDS AT HOMER

J	F	M	A	M	J	J	A	S	O	N	D
% Frequency wind speed $\geq$ 17 knots											
3.3	4.4	3.8	2.5	1.3	0.7	0.4	0.4	1.2	2.2	2.6	2.9
% Frequency wind speed $\geq$ 28 knots											
0.1	0.1	0.1	0.1	0	0	0	0	0.1	0.1	0	0.1

Temperature - Temperatures in Kachemak Bay are generally representative of a maritime climate. Winters are mild, seldom getting colder than zero and summers are cool with the maximum temperatures seldom going above 70°F. The range between average maximum and minimum temperatures does not exceed 16 degrees during any of the 12 months.(3)

The mean annual temperature is around 36°F and has varied from 33°F to 38°F during the past thirty years. Table 5-10 shows the record lowest and highest temperatures for Homer.

TABLE 5-10

EXTREME TEMPERATURES AT HOMER

J	F	M	A	M	J	J	A	S	O	N	D
Absolute maximum temperature											
51	51	50	63	69	80	78	78	68	64	52	50
Absolute minimum temperature											
-18	-18	-21	-9	6	29	34	31	20	7	-7	-16

The mean number of days 32°F and below per year is around 200 days. Table 5-11 shows the monthly variations of mean number of days with freezing temperatures.

TABLE 5-11

MONTHLY VARIATION ON FREEZING TEMPERATURES AT HOMER

J	F	M	A	M	J	J	A	S	O	N	D
Maximum temperature 32°F and below											
19	12	10	2	0.5	0	0	0	0	1	11	19
Minimum temperature 32°F and below											
30	25	28	23	11	1	0	0.5	4	19	26	28
Minimum temperature 0°F and below											
5	3	2	0.5	0	0	0	0	0	0	0.5	4

5.2.4 Biota Distributions

Avifauna

The U.S. Fish and Wildlife Service[4] estimates that there are about twelve breeding ducks per square mile of suitable habitat in the Kachemak Bay area. Small numbers of Canada geese, cranes, and trumpeter swans also breed in this area. Breeding trumpeter swans are relatively abundant on upland pools.

Waterfowl use suitable areas in this region throughout the year. Winter use is restricted to coastal bays and other estuarine areas. Kachemak Bay is a major wintering area, supporting substantial numbers of mallards, sea ducks and sea birds. Large concentrations of birds are common on Fox River Flats during spring and fall migrations. A few trumpeter swans winter in the area during mild winters. Geese are an important segment of the bird population of these marshes, particularly in spring.

The Fox River Flats may have as many as 6,000 mallards during the spring. Smaller numbers of ducks and geese numbering in the hundreds are often found in such places as China Poot Bay and other bays and coves. Kachemak Bay contains numerous scoters, also.[1]

The fall buildup in the marshes begins in early August and peaks in late September. Frequently, 10,000 or more waterfowl occupy the area at that time. The marshes freeze over about mid-October in the upper Inlet and the migration is then at an end.[1]

A number of waterfowl surveys have been conducted over the lower Cook Inlet[1]. However, the key habitat areas are the Fox River Flats and Kachemak Bay. The major threat to waterfowl habitat is from offshore oil spills.

Marine Mammals

Lower Cook Inlet is a habitat for several species of marine mammals.

Harbor Seals - Seals are found throughout Kachemak Bay with concentrations found in Yukon Island, China Poot Bay and headwaters of the

Bay (Fox River). They are also present between Homer and Anchor Point but seldom reach north of this region[1]. Numbers are not known.

Sea Otters - Sea otters are present between English Bay and Seldovia. They number around 500. None are indicated for the Bay proper but as the population increases they are expected to expand into Kachemak Bay[4].

Sea Lions - A rookerie and hauling ground for sea lions is located on Flat Island near English Bay. Population is around 300 animals.[5] Other rookeries and hauling grounds are located further south away from the Bay.

Other - Beluga whales have been reported in the Cook Inlet. Population estimates vary between 100 to 400 whales depending on the season. Other whales and porpoises have been observed in the lower Inlet[1].

Fish

Various species of both finfish and shellfish are important to the economy of the lower Cook Inlet. All five North American species of Pacific salmon inhabit lower Cook Inlet in numbers. Kachemak Bay salmon resources are of particular importance, with the commercial catch varying between 46,759 to 232,389 during the past eight years. While the majority of the fish are destined for spawning areas outside Kachemak Bay, considerable numbers also spawn intertidally within the bay[1]. Dolly Varden are widely distributed about the Cook Inlet. They move down to Kachemak Bay where they are often caught during the summer. Dolly Varden is an important sport fish in many streams around Cook Inlet[1].

Herring have been harvested in Cook Inlet in considerable quantities, with catches reaching almost 20 million pounds. Herring are inshore in spring and summer with active spawning in the southern district in Kachemak Bay. They are most abundant in Kachemak Bay[1].

Shellfish, such as king crab, Tanner crab, dungeness crab, shrimp and clams are in abundance in the Kachemak Bay. Commercial harvests of these shellfish have reached 14 million pounds[1].

Kelp

Extensive kelp beds are found in Kachemak Bay especially on the north side of the bay east of Homer. On the south coast there are several kelp beds from Chugachik Island to English Bay. Isolated patches are found between Homer and Anchor Point.

Driftwood

There are numerous timber processing operations in the Cook Inlet region; all but one are of very limited size. At present, the only sizable venture is the South Central Timber Development Company operation at Takolof Bay near Seldovia. The majority of the logs processed at this mill do not come from this area, but are barged to the mill from Icy Bay (Yakataga)[1].

The extent of driftwood from timber operations and from rivers emptying into the Kachemak Bay is not known. Onsite inspection is probably necessary.

5.2.5 Evaluation of Approaches to Storage and Disposal of Recovered Oil in Lower Cook Inlet (Kachemak Bay)

Marine spills in Kachemak Bay will normally be readily accessible by local vessels (either Coast Guard or fishing vessels). Oceanographic conditions are normally not severe and, thus, the probability of recovering a spill is quite good as compared to other marine spill sites investigated. Adequate docking facilities at both Homer and Seldovia would facilitate handling and transfer of recovered oil. Suitable land areas for temporary storage containers exist on the Homer Spit and around Seldovia. There is no permafrost in the area. A road system connects Homer with Anchorage. Primitive roads along the north shoreline of Kachemak Bay provide access to most of that shoreline. Table 5-12 is an estimate of the feasibility of various approaches to storage and disposal of recovered oil.

In situ or controlled burning is recommended where it can be done safely if containment and recovery operations do not commence before significant spreading has occurred. In situ burning is also recommended where the threat of serious ecological damage exists. Barge-mounted vacuum trucks could be provided from other areas of Cook Inlet which could handle and immediately store spills up to approximately 1,000 barrels. Controlled burning in either portable burners or shoreline pits would normally be feasible anywhere within Kachemak Bay for any size of spill. Controlled burning of gasoline would be expected only in the event of a serious ecological threat and is assumed feasible for this area only because equipment such as vacuum trucks are available from Anchorage to safely handle the gasoline. Incineration of stored oil is similarly felt feasible in the Lower Cook Inlet area because of the adequate logistic support available from metropolitan areas.

Earth moving equipment is available at Homer which could be used to prepare sites for storage containers and construct secondary containment dikes. Landfill as a means of disposal is feasible in the area because of the road system connecting Homer to Anchorage and other cities on the mainland. The military dumps in the Anchorage area could probably accommodate spills of crude oil and residual fuel oil up to 1,000 barrels. Local dumps such as

TABLE 5-12

EVALUATION OF APPROACHES TO STORAGE AND DISPOSAL ALTERNATIVES
IN LOWER COOK INLET (KACHEMAK BAY)

Type of Product And Spill Size	In situ Burning		Immediate Storage Available		Temporary Storage In Portable Containers		Controlled Burning		Incineration		Landfill		Reprocess or use Directly		Transfer Off-Site	
	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
CRUDE OIL																
100 barrels	X		X		X		X		X		X		X		X	
1,000 barrels	X		X		X		X		X		X		X		X	
10,000 barrels	X			X	X		X		X			X	X		X	
50,000 barrels	X			X		X	X		X			X		X	X	
RESIDUAL FUEL OIL																
100 barrels		X	X		X		X		X		X		X		X	
1,000 barrels		X	X		X		X		X		X		X		X	
10,000 barrels		X		X	X		X		X			X	X		X	
50,000 barrels		X		X		X	X		X			X		X	X	
DISTILLATE FUEL OIL																
100 barrels	X		X		X		X		X			X	X		X	
1,000 barrels	X		X		X		X		X			X	X		X	
10,000 barrels	X			X	X		X		X			X	X		X	
50,000 barrels	X			X		X	X		X			X		X	X	
GASOLINE																
100 barrels	X			X		X	X			X		X	X		X	
1,000 barrels	X			X		X	X			X		X	X		X	
10,000 barrels	X			X		X	X			X		X	X		X	
50,000 barrels	X			X		X	X			X		X		X	X	

at Homer would likely be limited to quantities less than 100 barrels. It is felt that distillate fuel oil and gasoline cannot be disposed of in sanitary landfill areas.

Transfer of quantities of recovered oil in quantities up to 50,000 barrels is feasible from Homer by barge, tanker or land vehicle if a use can be found for the product elsewhere. Military or civilian facilities could probably utilize recovered distillate fuel oil by blending. Crude oil might similarly be used if weathering had not been severe. Oil recovered from Cook Inlet spills has been used for road oiling in the past. However, future restrictions on the use of oil on dirt roads and problems associated with handling weathered oil in oiling trucks suggest that use would be limited to lighter oils recovered from small spills.

Debris is not expected to be a severe problem in Kachemak Bay, with the possible exception of dead waterfowl. Driftwood is present due to local forests but is probably not sufficient in quantity to severely hamper oil storage or disposal. It is assumed that debris could be accommodated in portable totes and either burned at a convenient site or hauled to a local dump.

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5.3 UNIMAK PASS

5.3.1 Shoreline Characteristics

Unimak Island is about 50 miles long and 23 miles wide; it is extremely mountainous, bare of trees and generally grass-covered. The majority of the coast is rocky with steep cliffs and bluffs. Sand beaches are rare; usually being found only at the heads of bays. Beaches seldom extend more than 50 yards inland from the high-water line. The coast is exposed to the ocean swell and there is generally a heavy surf. Nearly all beaches present natural obstacles to landing by boat. The shores are generally precipitous; the breakers are heavy and in many cases the approaches are filled with jagged rocks and kelp beds.

Marshes are found in areas of the Unimak Bight and Urilia Bay. Several of the surrounding islands are grass-covered and have tundra characteristics. Unimak Pass is about 10 mi wide between the southwest end of Unimak Island and Ugamak Island, which is one of the smaller islands of the Krenitzin Group.(1) Figure 5.3 shows geographical features of the Unimak Pass region.

5.3.2 Oceanographic Conditions

Tide Ranges

The tidal range is not extremely large at Unimak Pass but the tidal currents are quite strong. The diurnal range of tide is around 5 feet. The mean lower low water at Cape Sarichef, is based on 108 high waters and 109 low waters, May 24-July 19, 1939, reduced to mean values. Elevations of other tide planes referred to this datum are given in Table 5-13.

TABLE 5-13

TIDAL RANGES FOR CAPE SARICHEF, UNIMAK ISLAND

	Feet
Highest Tide (estimated)	8.0
Mean Higher High Water	5.0
Mean High Water	4.7
Half Tide Level	3.1
Mean Low Water	1.5
Mean Lower Low Water	0.0
Lowest Tide (estimated)	-3.0

Source: U.S. Coast and Geodetic Survey, Anchorage, Alaska

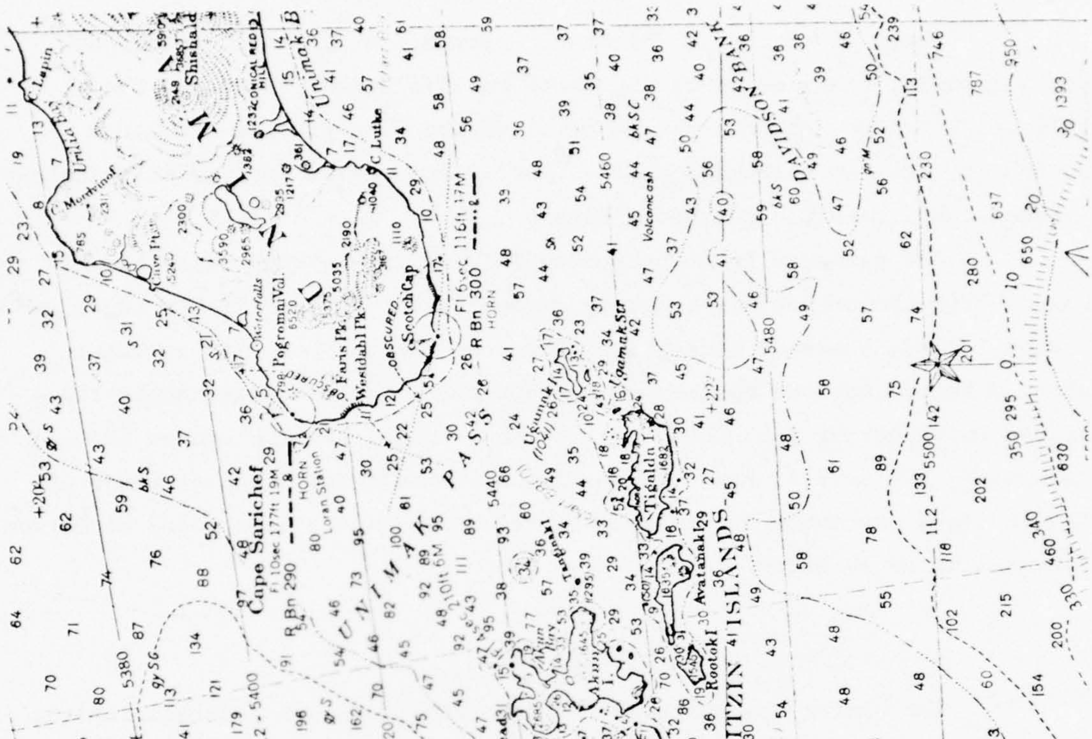

FIGURE 5-3. UNIMAK PASS (from C.&G.S. Chart 8802)

Currents

There is a general continual northward drift through the pass due to general circulation of the North Pacific Ocean. However, the velocities of the currents caused by tidal and wind effects are large enough to mark the northward drift. Whirls and eddies in wide distribution further complicate the current pattern.

All passages in the Aleutian Islands have strong currents. In Unimak Pass the current is probably strongest between Scotch Cap Light and Ugamak Island, where at strength of flood or ebb the velocity averages about 3 knots, but the maximum may exceed this figure during tropic tides when 6 knots during the flood and 6.5 knots during the ebb are to be expected. The current has a large diurnal constituent which at times of tropic tides may cause the current to set continuously in a flood direction for as much as 18 hours.(1)

Ice

The winter temperatures over the Aleutians are moderated by the warm waters of the Japan Current system. The islands are, therefore, usually free from ice. However, a severe winter could cause the northern ice pack to approach the Unimak Pass area. Some shore ice could form in localized areas.

5.3.3 Climatology

General Climate

The climate of Unimak Pass is maritime due to the ocean exposure. The daily weather is characterized by persistent overcast skies, high winds and severe storms. The weather is extremely localized, conditions of fog, low cloud ceilings and clear weather frequently being encountered within a distance of 20 miles. Clear weather over large areas seldom persists for long periods (12 hrs). An important local characteristic of the daily weather is that the northern shores of the islands have better weather and less fog than the southern shores.(1)

Significant Weather Elements

Snow - Snowfall has occurred in all months of the year at Cape Sarichef except September. The seasonal snowfall (Cold Bay) has varied from 28 to 86 inches since 1944. Table 5-14 shows the maximum snowfall that has occurred in 24 hours at Cape Sarichef, the greatest depth on ground and the mean number of days snowfall has exceeded one inch or more at Cold Bay.

TABLE 5-14

SNOWFALL STATISTICS FOR UNIMAK PASS*

J	F	M	A	M	J	J	A	S	O	N	D
Maximum in 24 hrs (in.)											
5	6	13	2	2	T	T	T	0	1.5	3.0	4.0
Greatest depth on ground (in.)											
10	7	16	3	1	0	0	0	0	3	6	9
Mean number* of days snowfall one inch or more											
3	3	3	2	1	0	0	0	0	1	2	3

* Cold Bay data

Wind - The prevailing wind is generally from the south-southeast but westerly directions may prevail at times. The mean monthly wind speeds vary from 10 knots to 16 knots with the stronger winds during the cooler months. Fastest observed 1-minute speeds have varied from 48 to 64 knots and have been usually from the east sectors. During the winter months strong winds result in low visibilities due to blowing snow.

Table 5-15 shows the percentage frequency of wind speeds equal or greater than 25 knots at Cape Sarichef.

TABLE 5-15

PERCENTAGE FREQUENCY OF STRONG WINDS AT CAPE SARICHEF

J	F	M	A	M	J	J	A	S	O	N	D
Percentage frequency wind speed $\geq$ 25 knots											
17.2	15.3	13.7	10.4	8.2	3.8	3.9	5.3	10.8	13.4	15.5	13.4

Temperature - The mean annual temperature for Unimak Pass is around 38°F but on a year-to-year basis it has varied from 35 to 40°F. As a result of the maritime climate, temperature extremes, both seasonal and diurnal, are generally small. Differences between maximum and miminum temperatures for all months average less than 10°. Cold air excursions into the area from the northern ice pack occasionally cause below-zero readings.[2] Tables 5-16 and 5-17 show extreme temperatures and the variations of freezing temperatures for Cape Sarichef.

TABLE 5-16

EXTREME TEMPERATURES AT CAPE SARICHEF

J	F	M	A	M	J	J	A	S	O	N	D
Absolute maximum temperature °F											
57	58	58	58	59	70	74	74	72	61	58	57
Absolute minimum temperature °F											
6	-1	-5	13	14	23	34	28	25	22	23	6

TABLE 5-17

MONTHLY VARIATION OF FREEZING TEMPERATURES AT CAPE SARICHEF

J	F	M	A	M	J	J	A	S	O	N	D
Mean number of days maximum temperature 32°F and below											
8	9	7	4	0.5	0	0	0	0	0.5	1	6
Mean number of days minimum temperature 32°F and below											
22	23	24	20	8	1	0	0.5	0.5	7	14	24
Mean number of days minimum temperature 0°F and below											
0	0.5	0.5	0	0	0	0	0	0	0	0	0

5.3.4 Biota Distribution

Avifauna

Bird populations in the Aleutian Islands have experienced many drastic changes in distribution, numbers and species composition since man

first visited the islands. Biologists are now making intensive investigations into bird population, distribution and numbers in the Aleutian Chain. They have discovered that more than 100,000 Emperor Geese winter in the islands each year. Some known seabird colonies are located on Kaligagan Island where Cassin's and Parakeet auklet reside and Unimak Island where the double-crested cormorant, black-legged kittiwake, and Aleutian tern reside.(3)

King(4) indicates that the Unimak Pass area is one of the most important bird gathering places in the northern hemisphere. This region is the last staging and feeding area for vast numbers of birds awaiting spring breakup in the Arctic each year. Likewise, birds fleeing the early arctic freezings linger in this rich coastal environment for weeks to rest and feed before continuing their migration south. Bristol Bay and its coastal zone is also the breeding ground for colonial seabirds numbering in the millions. It is the winter habitat for hundreds of thousands of diving ducks and seabirds, and the summer habitat for large numbers of shearwaters, fulmars, and murres.(5)

A number of bird surveys have been made in the Bristol Bay area(5)(6). King, et al.,(7) conducted a survey in Unimak Pass and found 29,125 birds in May and 39,568 in November of 1971-72.

Marine Mammals

Harbor Seal - Harbor seals are present throughout the Unimak Pass area. No large concentrations are known but the animals are abundant. A few seals are harvested annually in the area of Dutch Harbor.(3)

Sea Otters - Small concentrations of sea otters inhabit the water northeast of Tigalda Island and near Samalga Island. Smaller numbers occur throughout the area. Numbers are increasing steadily and there is the potential for an influx of large numbers of otters from Unimak Island. Otter population around north Unimak is 8,000 to 10,000 and increasing.

Sea Lions - The Aleutian Islands contain more sea lions than any other Alaska game management area. Population estimates of several rookeries and hauling grounds in the Unimak Pass area have been made and are listed below in Table 5-18. The population estimate given for each location is the highest number of sea lions that a biologist had seen at a location at a particular time. It is not an absolute figure but only an indication of the degree of use by sea lions.[3][8]

TABLE 5-18

SEA LION ROOKERIES AND HAULING GROUNDS NEAR UNIMAK PASS

Location	Population
Akutan Island (North Head)	714
Akun Island (Akun Head)	2,000
Akun Island (Billings Head)	100
Tanginak Island	600
Tigalda Island (Rock off west end)	10
Tigalda Island (Rock off northeast end)	750
Aiktak Island	600
Ugamak Island	13,400
Round Island	6,000
Unimak Island (Cape Sarichef)	200
Unimak Island (Oksenof Point)	4,000
Total	28,374

Other - Harbor porpoises, Dall porpoises, killer whales, Pacific pilot whales, Baleen whales and other whales inhabit the coastal and off-shore waters. The first three are very common.[6]

Fish

Finfish and shellfish are found in the Unimak Pass waters but most of the information concerning this subject has been directed toward the more important Bristol Bay area discussed in the next section.

Kelp

Kelp beds are very extensive along the coasts in the warm season but disappear entirely during the winter.

Driftwood

Driftwood may not be a debris problem but information is lacking. Onsite inspection would be required.

5.3.5 Evaluation of Approaches to Storage and Disposal of Recovered Oil at Unimak Pass

The Unimak Pass area offers few alternative approaches to storage and disposal of recovered oil. The rocky, inaccessible shorelines, remoteness, lack of ports and harbors, and completely exposed nature of all marine waters greatly minimizes the probability of high-seas oil recovery. The preferred method of disposal is clearly in situ burning. Dutch Harbor, approximately 40-50 nautical miles away is the nearest suitable harbor with adequate docking facilities for transfer and storage of recovered oil. Erection of temporary storage tanks would be no problem at Dutch Harbor because cleared sites are available and the area is free of permafrost. Abandoned military facilities there might be used to store quantities up to 10,000 barrels or more if the condition of the tanks were checked first. Incineration or controlled burning is felt feasible only at a sheltered location or accessible onshore area such as Dutch Harbor. Table 5-19 is an estimate of the feasibility of various approaches to storage and disposal of oil.

Debris is not expected to present a significant problem as driftwood is not common and the area is ice-free. Dead birds could, however, pose a significant problem if the spill were to occur during peak periods of waterfowl migration.

TABLE 5-19

EVALUATION OF APPROACHES TO STORAGE AND DISPOSAL ALTERNATIVES AT UNIMAK PASS

Type of Product And Spill Size	In situ Burning		Immediate Storage Available		Temporary Storage In Portable Containers		Controlled Burning		Incineration		Landfill		Reprocess or use Directly		Transfer Off-Site	
	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
CRUDE OIL																
100 barrels	X			X	X			X	X			X		X		X
1,000 barrels	X			X		X		X	X			X		X		X
10,000 barrels	X			X		X		X		X		X		X		X
50,000 barrels	X			X		X		X		X		X		X		X
RESIDUAL FUEL OIL																
100 barrels		X		X	X		X		X			X		X		X
1,000 barrels		X		X		X	X		X			X		X		X
10,000 barrels		X		X		X	X			X		X		X		X
50,000 barrels		X		X		X	X			X		X		X		X
DISTILLATE FUEL OIL																
100 barrels	X			X	X			X	X			X		X		X
1,000 barrels	X			X		X		X	X			X		X		X
10,000 barrels	X			X		X		X	X			X		X		X
50,000 barrels	X			X		X		X		X		X		X		X
GASOLINE																
100 barrels	X			X		X		X		X		X		X		X
1,000 barrels	X			X		X		X		X		X		X		X
10,000 barrels	X			X		X		X		X		X		X		X
50,000 barrels	X			X		X		X		X		X		X		X

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5.4 KVICHAK BAY

5.4.1 Shoreline Characteristics

The Kvichak Bay is at the head of Bristol Bay. The bay is an important fishing area for red salmon and there are several canneries in its northern part. A large portion of the bay is an extensive tidal flat. The approach from the southwest is restricted to a channel about 3 miles wide near Big Flat, an extensive tide flat extending off the east shore, and by Dead Man Sands on the west shore. Some sandy areas are located on the tidal flats and scattered marsh areas are adjacent to the tidal flats. Bluffs are located in various places around the perimeter of the bay. A large share of the land beyond the bluffs is tundra. Figure 5-4 shows the geographical features of Kvichak Bay.

5.4.2 Oceanographic Conditions

Tide Ranges

As in the Cook Inlet, there is considerable amplification of the tide toward the head of Bristol Bay. Table 5-20 presents tidal ranges for Kvichak Bay.[1]

TABLE 5-20

TIDAL RANGES FOR KVICHAK BAY

Location	*Mean Range (ft)	**Diurnal Range (ft)
Egegik River (Entrance)	13.8	18
Kvichak Bay (Middle Bluff)	15.1	19.7
Naknek River (Entrance)	18.4	22.6
Kvichak	13.8	16.4

* Mean range is the difference in height between mean high water and mean low water.

** Diurnal range is the difference in height between mean higher high water and mean lower low water.

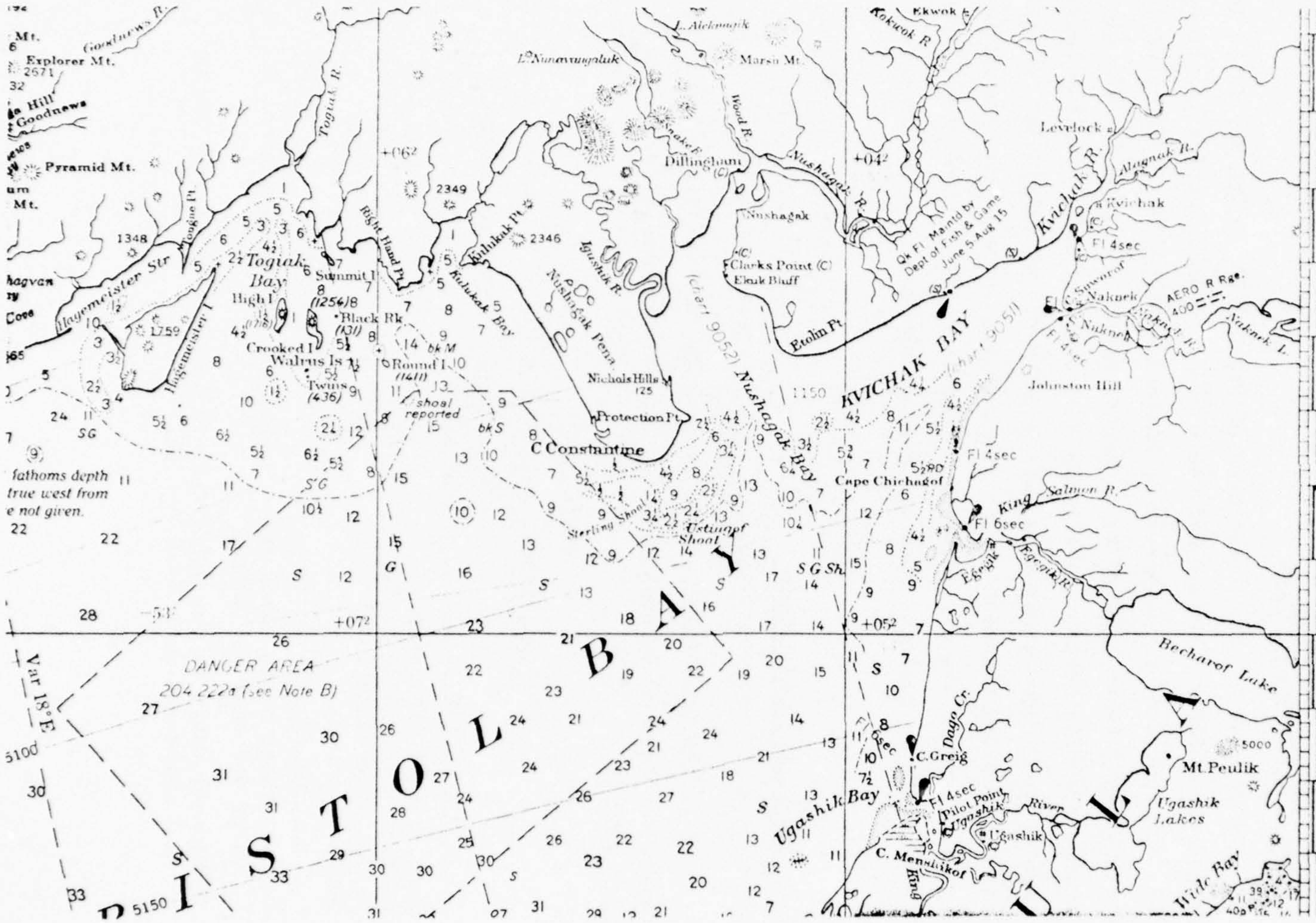

FIGURE 5-4. KVICHAK BAY (from C.&G.S. Chart 9302)

Currents

Currents in Kvichak Bay are chiefly governed by the tides except for storm-induced wind currents. In the Bay and Kvichak River the current is very strong; consequently, the channel shifts each year. The current velocity is 3.5 knots in the lower part of the bay and 2.5 knots in the main ship anchorage off Naknek.(2) In many estuarine areas, the ebb tidal currents considerably exceed the flood, due to the influence of river flow.(1) Winds in excess of 20 knots, opposed to currents, make the Bay quite rough for vessels of light draft.(2)

Ice

Bristol Bay lies at the southern boundary of the area influenced by true seasonal ice. The highly variable temperature, tide, and wind regimes in the Bay causes the ice to constantly change in shape and character. Formation of the ice begins in fall and by mid-October the more dilute and sheltered lagoons will start to show ice cover. Considerable fresh water ice formed in the larger tributary rivers may enter the Bay. The most severe ice conditions occur in February and March. At this season there may be many scattered reaches of shore-fast ice in the Bay, but the considerable tidal amplitudes tend to keep ice in this area broken up. The ice usually does not break up until May.(2)

5.4.3 Climatology

General Climate

The Kvichak Bay region is characterized by cloudy skies, mild temperatures and moderately heavy precipitation. Surface winds are strong at times and temperature extremes depend on whether air trajectories are over land or water. A major storm track crosses the eastern Bering Sea during the period from late July to early September.

Significant Weather Elements

Snow - Snow has occurred in all months of the year except July and August. The seasonal snowfall has varied from 26 to 67 in. since 1942. Table 5-21 presents the maximum snowfall that has occurred in 24 hrs, the greatest depth on ground and the mean number of days snowfall has exceeded one inch or more at King Salmon.(3)

TABLE 5-21

SNOWFALL STATISTICS FOR KING SALMON

J	F	M	A	M	J	J	A	S	O	N	D
Maximum in 24 hrs (inches)											
8.5	9.3	9.5	4.5	1.6	1.2	0	0	0.6	7.3	8.6	6.4
Greatest depth on ground (inches)											
12	8	12	7	T	0	0	0	0	8	7	13
Mean number of days snowfall one inch or more											
2	2	3	2	0.5	0.5	0	0	0	1	2	3

Wind - The prevailing wind direction is from the northerly direction during the cooler months and from southerly directions during the warmer months. Mean monthly wind speeds are between 9 and 10 knots and are slightly lower during the summer months. Fastest observed 1-minute speeds have varied from 40 to 62 knots and have been from the east sector. High winds can cause blowing snow during the winter. Table 5-22 shows the percentage frequency of wind speeds equal or greater than 17 and 28 knots, respectively.(4) Strongest winds occur during the winter.

TABLE 5-22

PERCENTAGE FREQUENCY OF STRONG WINDS AT KVICHAK BAY

J	F	M	A	M	J	J	A	S	O	N	D
% Frequency wind speed ≧ 17 knots											
19.1	17.6	18.6	12.5	14.5	8.8	5.6	8.9	12.1	12.3	15.9	16.2
% Frequency wind speed ≧ 28 knots											
2.4	1.4	1.8	0.9	1.2	0.8	0.3	0.4	1.0	1.2	1.8	1.2

Temperature - Mean annual temperature around Kvichak Bay is 33°F, however, on a year-to-year basis it has varied from 28°F to 36°F. Table 5-23 shows the extreme temperature for each month at King Salmon.

TABLE 5-23

EXTREME TEMPERATURES AT KING SALMON

J	F	M	A	M	J	J	A	S	O	N	D
Absolute maximum temperature °F											
47	46	54	59	75	80	85*	84	71	62	48	48
Absolute minimum temperature °F											
-34	-35	-42**	-4	13	29	33	32	18	-1	-14	-30

* Temperature of 88°F in June 1953 was recorded at another location.

** Coldest on record -43°F in January 1919.

The extreme maximum temperature for King Salmon is 88°F, but days in summer with maximum readings reaching 80° mark are extremely rare. July, the warmest month, has an average of only 5 days when the temperatures reach 70° or above.[3] Table 5-24 presents the mean number of days when temperatures are 32°F and below and 0°F and below.

TABLE 5-24

MONTHLY VARIATION OF FREEZING TEMPERATURES AT KING SALMON

J	F	M	A	M	J	J	A	S	O	N	D
Mean number of days maximum temperature 32°F and below											
25	17	15	7	1	0	0	0	0	7	15	21
Mean number of days minimum temperature 32°F and below											
30	26	28	25	14	1	0	0.5	5	23	26	29
Mean number of days minimum temperature 0°F and below											
15	12	8	1	0	0	0	0	0	1	3	15

5.4.4. Biota Distribution

Avifauna

The Kvichak Bay region and surrounding tundra areas are a major nesting, molting, staging and migration area for waterfowl and seabirds. The Alaska Department of Fish and Game estimates that the area supports about 32 breeding ducks per square mile of suitable habitat. There are around 18 species of breeding waterfowl species including Canada geese and trumpeter swans.

The area is extremely important as a spring and fall waterfowl staging and migration area. All or nearly all of North America's blackfront, emperor geese, cackling Canada geese and Aleutian Canada geese use habitats in this area.

Many hundreds of thousands of snow geese, white-fronted geese, lesser Canada geese, sandhill cranes, dabblers, divers and sea ducks are present during spring and fall months. Nearly all of the large spring and fall concentration of birds occur in intertidal, estuarine and river delta areas.

Bristol Bay and its coastal zone is also the breeding ground for colonial seabirds numbering in the millions. It is the winter habitat of hundreds of thousands of diving ducks and sea birds.

A number of bird surveys have been made in the Bristol Bay region but not specifically for the Kvichak Bay area. A survey(5) during May 3

through May 8, 1972 indicated that loons, cormorants, geese, swans, ducks, gulls, kittiwakes, terns, jaegers and alcids were present near the Kvichak Bay region. Ducks were numbered in the 100's or more. An earlier survey[5] during July 13 to August 20, 1969 on seabirds indicated 8 different species of seabirds with gulls and phalaropes numbering in the 1000's.

Marine Mammals

Harbor Seal (Land) - High concentrations of seals reside just off Egegik Bay and they are present in all the coastal waters of Kvichak Bay. Population is unknown.

Sea Otters - None are known in Kvichak Bay because of sea ice conditions. In 1970, significant numbers of sea otters had reached Port Heiden and stray animals were seen as far north as Ugashik Bay. However, extreme sea ice conditions in the springs of 1971 and 1972 caused considerable mortality.

Sea Lions - Few are located in Kvichak Bay, apparently sea lions do not utilize the north side of the Alaska Peninsula very extensively.

Bearded Seal, Ice Breeding Harbor Seal, Ringed Seal and Walrus - These marine mammals are mainly associated with sea ice and usually migrate with the seasons. A number of these animals were reported in the Bristol Bay during a 1972 bird survey.[5]

Whales - Gray whales commonly occur along the northshore of the Alaska Peninsula. Beluga whales are very abundant in Bristol Bay during ice-free periods. They occur most frequently in Kvichak Bay and Nushagak Bay. In spring when the Naknek River becomes ice free, Belugas ascend the river to feed, sometimes going as far as King Salmon and even beyond. Belugas also ascend the Kvichak and Nushagak Rivers, frequently passing beyond the village of Levelock on the Kvichak River. They are most abundant in the river during the month of May and the first two weeks of June.[1]

Fish

Five species of salmon utilize three river systems of the Kvichak Bay for spawning purposes. The Sockeye Salmon are the most abundant and they peak in numbers in early July. The commercial harvest varies from a few

hundred thousand to over 30 million fish annually. Chinook, Chum, and Pink Salmon are the next in abundance and their peak numbers vary from mid-June to early August. Coho salmon are the least abundant and peak in numbers in late August. Other fish and shellfish are present but are not as significant as the salmon runs.(1)

Kelp

Kelpbeds are not present in the Kvichak Bay area.

Driftwood

Information is not available on the distribution of driftwood on the shores. The coastal areas of the Kvichak Bay region are generally devoid of trees. Rivers entering the Bay probably discharge certain amounts of wood debris especially after severe storms. Canneries, ships and coastal villages probably add an unknown amount of driftwood as well as other types of debris.

5.4.5 Evaluation of Approaches to Storage and Disposal of Recovered Oil in Kvichak Bay

Marine oil spills within Kvichak Bay in all probability will end up on the north or south shoreline of the bay if not contained during the summer as a result of prevailing northerly winds and an observed counter-clockwise surface current. The very shallow waters and extensive mud flats throughout the area severely limit approach to all shorelines by deep draft vessels. Road systems do not exist along the shorelines which restricts on-shore travel to All Terrain Vehicles during the summer months because of the tundra. Winter travel along the shorelines is much easier. The seasonal ice existing during winter months would trap released petroleum products, but access to the oil would be limited by the unavailability of shallow draft icebreakers. Table 5-25 is an estimate of the feasibility of various approaches to storage and disposal of recovered oil. The feasibility of some approaches could change on a seasonal basis.

In situ burning is the preferred method for disposal if safety permits and the product is combustible, particularly in the case of large spills. Transfer operations to shore would be seriously hampered by the shallow waters in summer and there are no docking facilities in the entire area that can accommodate deep draft vessels except at high tide. Delays caused by the tides could be minimized only if large barges were immediately available. Local fishing vessels are numerous in the area during the summer and could be adapted for oil handling and transfer operations for spills up to approximately 1,000 barrels. Winter operations on the ice would essentially be limited to helicopters which severely limits the size of equipment.

The most suitable storage areas are located around towns with adequate docking facilities. Permafrost is common throughout the shoreline areas and the soil is moist which would preclude establishment of sound footings for rigid tanks. Pillow tanks would be the best type of temporary storage container along the shorelines. Immediate storage of oil in quantities up to 100 barrels is assumed feasible using local vessels.

TABLE 5-25

EVALUATION OF APPROACHES TO STORAGE AND DISPOSAL ALTERNATIVES AT KVICHAK BAY

Type of Product And Spill Size	In situ Burning		Immediate Storage Available		Temporary Storage In Portable Containers		Controlled Burning		Incineration		Landfill		Reprocess or use Directly		Transfer Off-Site	
	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
CRUDE OIL																
100 barrels	X		X		X		X		X		X		X			X
1,000 barrels	X			X	X		X		X			X		X		X
10,000 barrels	X			X	X		X		X			X		X		X
50,000 barrels	X			X		X	X			X		X		X		X
RESIDUAL FUEL OIL																
100 barrels		X	X		X		X		X		X		X			X
1,000 barrels		X		X	X		X		X			X		X		X
10,000 barrels		X		X	X		X		X			X		X		X
50,000 barrels		X		X		X	X			X		X		X		X
DISTILLATE FUEL OIL																
100 barrels	X		X		X		X		X			X	X			X
1,000 barrels	X			X	X		X		X			X		X		X
10,000 barrels	X			X	X		X		X			X		X		X
50,000 barrels	X			X		X	X		X			X		X		X
GASOLINE																
100 barrels	X			X		X	X			X		X		X		X
1,000 barrels	X			X		X	X			X		X		X		X
10,000 barrels	X			X		X	X			X		X		X		X
50,000 barrels	X			X		X	X			X		X		X		X

Adequate dumpsites do not exist for disposal of spills over approximately 100 barrels because all of the towns in the area are quite small. Controlled burning as the released petroleum products reach the shorelines is felt to rank second to in situ burning as a preferred method. The soft nature of the shoreline soils simplifies excavation and light construction would be available in towns at the head end of the bay.

Incinerators brought into the area and mounted on barges would provide the most effective means of disposal if the oil spill had been contained and/or temporarily stored. However, the problems of moving a barge through the winter ice could be problematic in the shallow waters. Transfer off-site is not felt feasible due to travel distances approaching 1,000 nautical miles to the nearest metropolitan areas with suitable docking facilities. Direct use of the recovered products would be limited to the smaller spills and probably further limited to distillate fuel oils.

Debris in the Kvichak Bay area during summer months would most likely be dead waterfowl. Driftwood is not common. Winter ice would constitute a severe debris problem during the winter. Oil-contaminated ice would best be handled in portable incinerators. Dead birds and other debris could be collected in totes and either be stacked and burned or incinerated in portable units. Gill nets used by local fishermen are readily available throughout the area and could be used to collect debris by sweeping.

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5.5 UMIAT

5.5.1 Site Characteristics

Umiat is a small village occupied only seasonally located in a shallow inland valley in the Colville River within the arctic foothills. It is located about 50 miles north of the Brooks Range and 75 miles south of the arctic coast. The terrain is relatively irregular consisting of tundra cliffs and bluffs and underlain by extensive permafrost.

In the summer vegetation of any height is sparse consisting mainly of marshes, small lakes and a number of unique patterns and features produced by permafrost and frost action. Among the most prominent are polygonal ground, stove nets, garlands and stripes, solifluction sheets and lobes, thaw lakes, beaded drainage, pingos and frost scars or boils.(1)

During the winter, the frozen status of the soil and the blanket of snow cover over seven to nine months are effective in leveling the terrain surface and prevention of wind erosion of arctic soils. During the summer thaw period, the tundra mat remains effective as a barrier to wind erosion except in localized areas where animals have torn holes in the tundra. Gravel and sand dunes are common along the rivers. Figure 5-5 shows the geographical features for the Umiat area.

5.5.2 Climatology

General Climate

The climate of Umiat is characterized in summer by cool and light winds, much cloudiness, light precipitation, and frequent drizzle. In winter, cloudiness decreases and very cold temperatures and katabatic winds prevail inland. By mid-September a snow cover is generally established, builds to a depth of one or two feet in March and April and melts in June or July.

Significant Weather Elements

Snow - Snow has occurred in all months of the year and the mean annual snowfall is around 31 in. a year. A continuous snow cover has generally formed throughout the area by mid-September. The snow cover clears away about

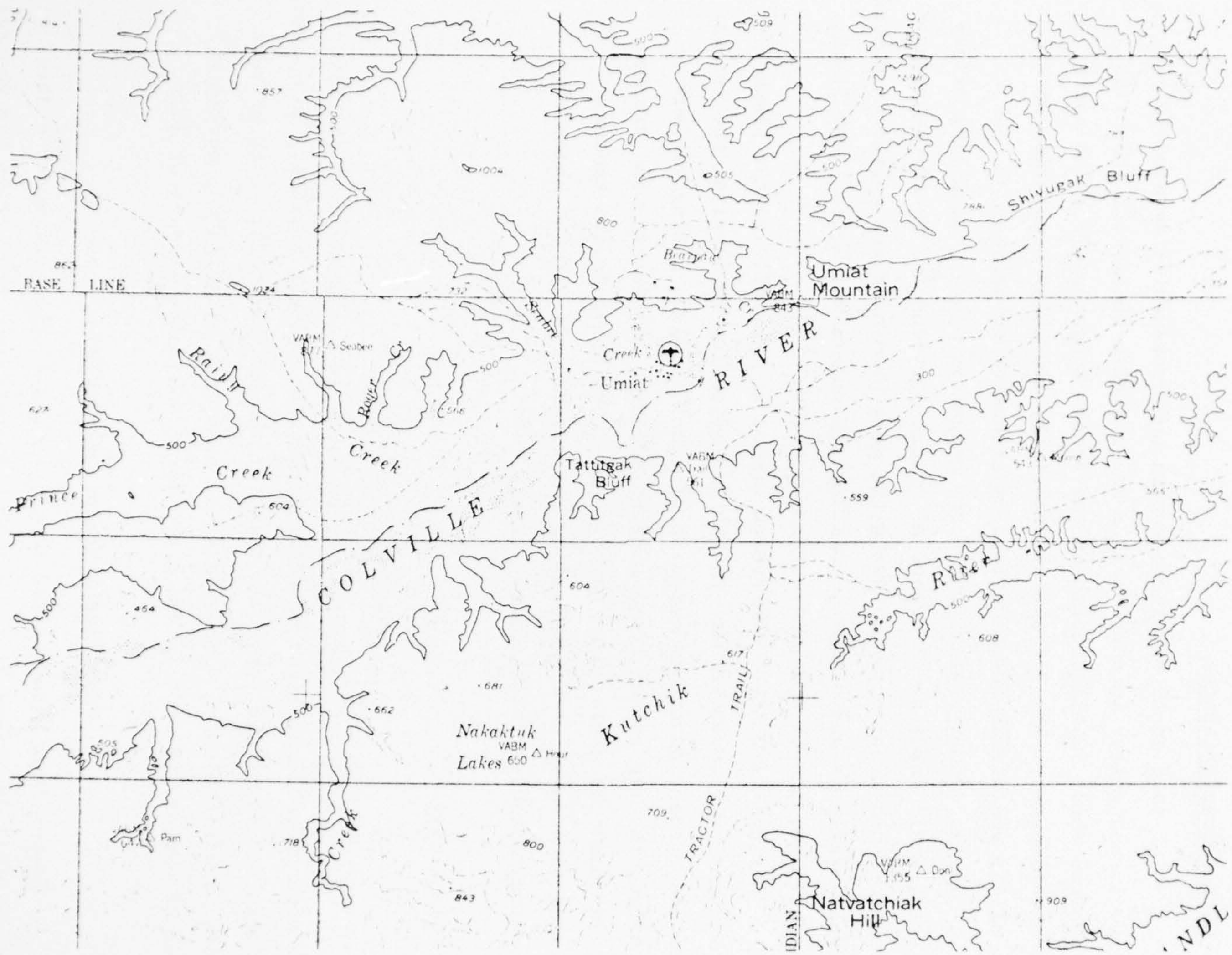

FIGURE 5-5. UMIAT (from U.S.G.S. Alaska Topographic Series)

mid-June. Snow depths build up slowly but steadily to a maximum, in late March or early April to around 15 - 22 in. at Umiat. During January, February, and March snow cover is never less than 7 in.[2] Table 5-26 shows the maximum snowfall that has occurred in 24 hrs, mean number of days with snowfall 1.5 in. or greater and mean snow depth.

TABLE 5-26

SNOWFALL STATISTICS FOR UMIAT

J	F	M	A	M	J	J	A	S	O	N	D
Maximum in 24 hrs (inches)											
2.4	3.0	2.2	4.2	1.9	2.1	T	1.9	3.3	3.7	2.7	2.4
Mean number of days snowfall $\geqq$ 1.5 inches											
0.8	0.4	0.4	0.7	0.3	0.1	0.0	0.3	0.4	1.3	1.2	0.9
Mean snowdepth (inches)											
13.3	14.5	14.2	14.9	7.5	0.5	0.0	T	1.4	4.0	7.8	10.4

Wind[2] - *Umiat, which lies in a shallow west-east inland valley,* experiences frequent easterlies during the summer, but in winter katabatic (down-slope) winds prevail i.e., blowing down the valley from the west. An occasional storm can strengthen the general gradient flow from the west resulting in stronger westerlies. Wind frequency at Umiat is high, especially during the fall and winter. Average monthly wind speeds vary between 5 and 8 knots. Strong winds during the winter can cause considerable blowing snow.

During the winter period when sun crusts do not develop on the snow cover, the hardness of the snow depends on the wind speed. In general, the higher the wind speed the greater the hardness.

Temperature - Mean annual temperature for Umiat is around 10°F. Temperature extremes and average diurnal ranges by months are shown in Table 5-27.

TABLE 5-27

MONTHLY TEMPERATURE EXTREMES AND AVERAGES

DIURNAL RANGES (°F) AT UMIAT

J	F	M	A	M	J	J	A	S	O	N	D
Absolute Maximum Temperature (°F)											
30	28	35	40	55	74	85	77	63	45	43	31
Absolute Minimum Temperature (°F)											
-62*	-63**	-50***	-46	-22	20	30	24	-6	-27	-53	-56
Diurnal Range											
17	16	18	22	24	16	20	23	13	15	16	14

* -78°F unofficially reported 15 January 1955

** -76°F on another summary.[3]

*** -52°F on another summary.[3]

The equivalent chill temperature (wind chill) is by far the most important temperature value expressed for this area because it combines the effect of wind and temperature in heat loss. Winter winds frequently drive wind chill factors to -60°F (-46°C) and lower. The combination of darkness and exteme cold in winter makes outdoor work difficult and often hazardous.[1,4]

<u>Ice</u> - At Umiat, the Colville River on the average breaks up around 24 May ± 12 days. The average date for the freeze-up where it is safe for a man to walk on the ice is around 18 October.[2]

5.5.3. Biota Distribution

Avifauna[1,5]

The harsh arctic climate is a primary factor determining waterfowl and seabird distribution and density, as well as survival and productivity. The foothill regions near Umiat is inhabited by approximately 84 bird species, most of which are summer migrants. The dominant species are aquatic and semiaquatic birds, such as geese, ducks, cranes, swans, shorebirds, seabirds, and gulls. The Umiat area is also a key breeding area for Peregrine falcons.

The majority of the land area is important nesting habitat, and the nearshore waters are utilized heavily by waterfowl and other aquatic birds. Most birds occur locally only from May through September and travel all the continental flyways and, in many cases, the international flyways. Winter residents number 8 or 9 species. The area serves as a major migration route and refuge for millions of birds breeding both in the area and in the Canadian Arctic.

Population estimates of the bird fauna for Umiat are incomplete. Waterfowl and seabirds favor the coastal plains with bird populations decreasing as distance from the coast increases. Aquatic and semiaquatic birds notably achieve the highest densities in the extensive low, marshy areas. Waterfowl densities vary as wetland densities vary. Highest densities occur 80 to 96 kilometers inland from the coast. Bird populations are indicated as low density in the Umiat area except for the Peregrine falcon.

Small Land Mammals[1]

The arctic ground squirrel, hoary marmot, lemmings, shrews and voles inhabit the Umiat area and could end up as debris in a large oil spill. Populations are not known and probably fluctuate year to year due to predators and other factors.

5.5.4 Evaluation of Approaches to Storage and Disposal of Recovered Oil at Umiat

Umiat is nearly a classic example of the remoteness of Alaska. It is merely a location with an airfield and no population. Virtually all approaches to storage and disposal are problematic. In situ burning during the summer could not be attempted without risk of setting the tundra on fire. Even locating the spilled oil during winter darkness would be most difficult. Controlled burning or incineration of petroleum products is the preferred method for this area until more is known about the burning properties of the tundra during the warmer seasons. Winter spills could safely be burned in situ if they could be located and the product were combustible. Table 5-28 is an estimate of the feasibility of various approaches to storage and disposal of recovered oil.

Immediate storage of crude oil and lighter oil products would be possible during the summer by pumping down a nearby thaw lake and subsequently pumping the oil onto the surface. The Umiat area is completely underlain with permafrost, so temporary storage would be limited to pillow tanks.

All transportation of personnel and equipment to and from Umiat would have to be by air which precludes transfer of large quantities of recovered products from the site. Portable incinerators could normally be air-transported to the site and operated only during the season of extended daylight due to logistic and field support restrictions. There would be no local use for any recovered product.

Debris in the area is expected to consist primarily of dead birds, small land mammals, and small pieces of dead vegetation during the summer. Snow and ice would pose severe debris problems during the winter. Debris would probably have to be llected and handled by hand operations due to transport restrictions across the tundra.

TABLE 5-28

EVALUATION OF APPROACHES TO STORAGE AND DISPOSAL ALTERNATIVES

AT UMIAT

Type of Product And Spill Size	In situ Burning		Immediate Storage Available		Temporary Storage In Portable Containers		Controlled Burning		Incineration		Landfill		Reprocess or use Directly		Transfer Off-Site	
	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
CRUDE OIL																
100 barrels	X			X	X		X		X			X		X		X
1,000 barrels	X			X	X		X		X			X		X		X
10,000 barrels	X			X	X		X		X			X		X		X
50,000 barrels	X			X		X	X			X		X		X		X
RESIDUAL FUEL OIL																
100 barrels		X		X	X		X		X			X		X		X
1,000 barrels		X		X	X		X		X			X		X		X
10,000 barrels		X		X	X		X		X			X		X		X
50,000 barrels		X		X		X	X			X		X		X		X
DISTILLATE FUEL OIL																
100 barrels	X			X	X		X		X			X		X		X
1,000 barrels	X			X	X		X		X			X		X		X
10,000 barrels	X			X	X		X		X			X		X		X
50,000 barrels	X			X		X	X		X			X		X		X
GASOLINE																
100 barrels	X			X		X	X			X		X		X		X
1,000 barrels	X			X		X	X			X		X		X		X
10,000 barrels	X			X		X	X			X		X		X		X
50,000 barrels	X			X		X	X			X		X		X		X

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5.6 OFFSHORE NOME

5.6.1 Shoreline Characteristics[1]

The coast from Cape Nome to Cape Rodney, except abreast of Sledge Island, is a relatively straight stretch of low sand beach with no projecting points, and higher land some distance back. Figure 5-6 shows the area offshore of Nome. North of Sledge Island for a distance of several miles, the hills slope down to the beach, giving this part of the coast the appearance of a point. The stretch of the beach is broken by a number of small rivers where hydraulic and placer mining is in progress. The entrances to Nome, Snake, Penny and Sinuk Rivers have shifting bars. Marshes exist near the mouth of the Snake River and in the vicinity of the Sinuk River and Cape Rodney.

Sledge Island 4.5 miles offshore, is a rocky flat-topped island except near the southern extremity where the highest point, a 760-foot jagged mountain exists. Ruins of abandoned habitations are located on the sandspit on the northern end of the island and along the beach about midway of the eastern side. Nome, the metropolis of northwestern Alaska, is on the beach at the mouth of the Snake River, 11 miles westward of Cape Nome.

5.6.2 Oceanographic Conditions

Tide Ranges

Tidal ranges are relatively small and diurnal. The diurnal range of the tide is 1.6 feet. The water levels are influenced more by the wind than tide. It is reported that an offshore wind may cause a level 2 to 3 feet below mean lower low water for days at a time and storms have caused a level of 14 feet above mean lower low water.[1]

The mean lower low water at Nome is based on 4 months of records, July-August 1969 and July 19-September 17, 1970, reduced to mean values. Elevations of other tide planes referred to this datum are given in Table 5-29.

AD-A032 749 BATTELLE MEMORIAL INST RICHLAND WASH PACIFIC NORTHWE--ETC F/G 13/2
TEMPORARY STORAGE AND ULTIMATE DISPOSAL OF OIL RECOVERED FROM S--ETC(U)
DEC 75 P L PETERSON, R A YANO, M M ORGILL DOT-CG-23223-A

UNCLASSIFIED USCG-D-181-75 NL

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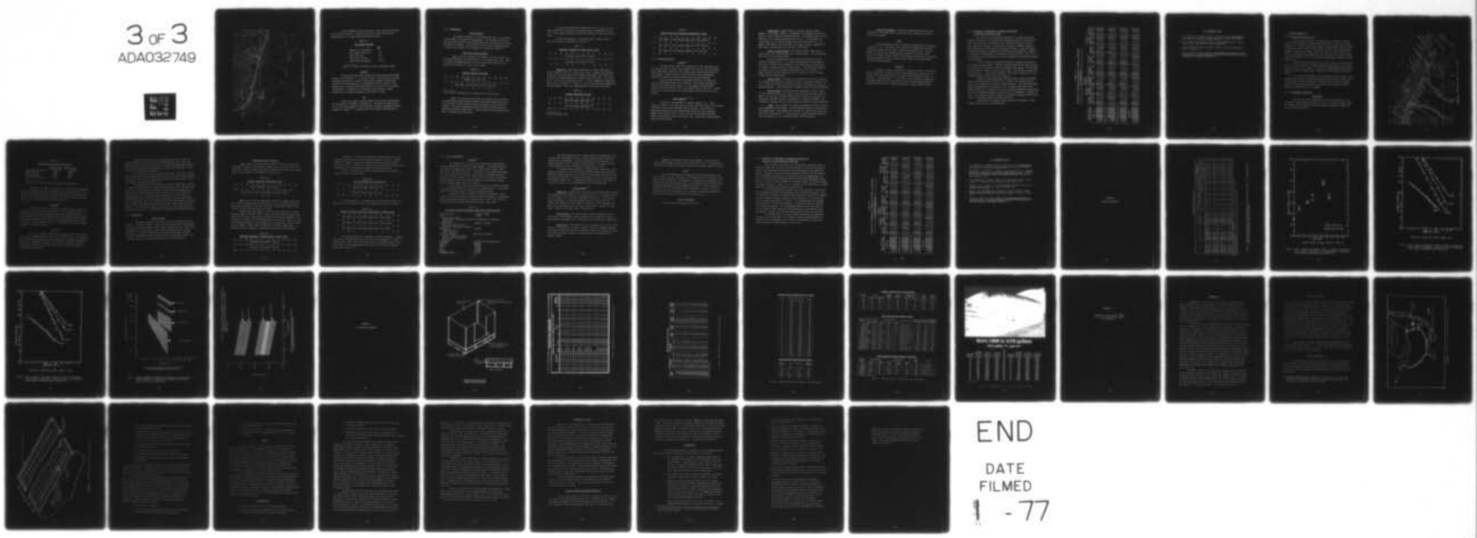
ADA032749



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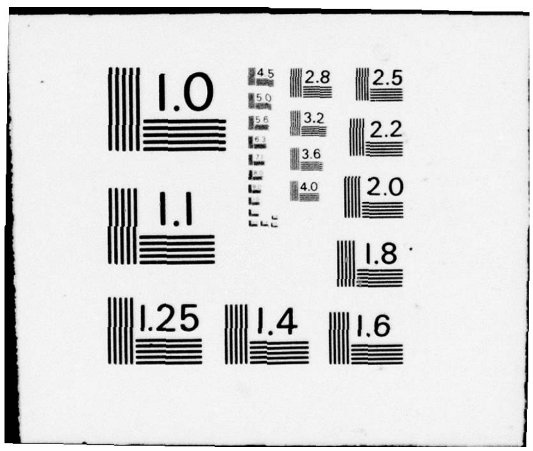
1.0
4.5
5.0
5.6
2.8
3.2
3.6
4.0
2.5
2.2
2.0
1.1
1.8
1.25
1.4
1.6

FIGURE 5-6. OFFSHORE NOME (From C.&G.S. Chart 9380)

A recent (November 1974) storm surge at Nome covered Front Street with five feet of water. The water level due to this storm surge was approximately 25 ft or more above mean lower low water.

TABLE 5-29

TIDAL RANGES FOR NOME

	Feet
Highest tide (estimated)	5
Mean higher high water	1.6
Mean tide level	0.8
Mean lower low water	0.0
Lowest tide (estimated)	-2 1/2

Source: U.S. Coast and Geodetic Survey, Anchorage, Alaska.

Currents

Observations on the tidal currents have been made between Sledge Island and the mainland.[1] The tidal current is diurnal with an average northwestward velocity of about 1.0 knot, and an average southeastward velocity of 0.5 knot giving a new northwestward drift of about 0.5 knot. Maximum velocity observed during observations was about 1.5 knots setting northwestward. In addition to these general tide currents, coastal currents may be strongly influenced by the effects of wind.

Ice

Coastal ice begins to form at Nome bet een October and November; the average date of freezeup is November 12. Navigation is difficult due to ice from early December to early June and is usually suspended from late December to mid-May.[1] Average date for ice breakup is around May 29.

5.6.3 Climatology

General Climate

The climate of Nome is of the transitional type, i.e., maritime during summer and continental during winter. The maritime influence of the open waters of Norton Sound is effective only from early June to about the middle of November. The freezing of Norton Sound in November causes a rather abrupt change from a maritime to a continental climate.(2)

Significant Weather Elements

Snow - Snow has occurred in all months of the year except July. The seasonal snowfall has varied from 17 to 103 inches since 1933. Table 5-30 shows the maximum snowfall in 24 hrs and the mean number of days snowfall has exceeded one inch or more at Nome.

TABLE 5-30

SNOWFALL STATISTICS FOR NOME

J	F	M	A	M	J	J	A	S	O	N	D
Maximum in 24 hours (in.)											
7.8	4.7*	5.0	6.3	5.3	0.9	0	0.1	2.6	6.6	7.6	8.4
Mean number of days snowfall one inch or more											
3	2	3	2	1	0	0	0	0.5	1	3	3

* 14.0 inches in February 1920 at another site in the locality.

Wind - The prevailing wind directions during the winter months are east through north with mean monthly wind speeds varying from 9 knots to 10.5 knots. Fastest observed 1-minute speeds have varied from 30 to 48 knots. Velocities exceeding 61 knots have been recorded during all months from October through March. Strong wind speeds are associated with east or southwest wind directions.

Strong winds during winter months when there is snow cover can cause blowing snow conditions that severely hinder transportation in the area. Storm surges (southwest winds) have inundated the low-lying coastal areas.

Percentage frequency of wind speeds equal or greater than 17 knots and 28 knots are presented in Table 5-31.

TABLE 5-31

PERCENTAGE FREQUENCY OF STRONG WINDS AT NOME

J	F	M	A	M	J	J	A	S	O	N	D
% frequency wind speed ≥ 17 knots											
22.0	21.5	15.9	15.3	8.2	4.8	5.7	6.9	13.1	11.8	21.0	15.3
% frequency wind speed ≥ 28 knots											
2.6	3.8	1.5	0.8	0.1	0	0.1	0	0.5	0.6	2.0	1.7

Temperature - Mean annual temperature at Nome is 26°F and has varied from 22°F to 30°F on a year-to-year basis. Temperatures generally remain well below freezing from the middle of November to the latter part of April, with January usually the coldest month of the year. The record low is -47°F and the record high is 86°F. A "thaw" temperature singularity often occurs in January.(2) Tables 5-32 and 5-33 show extreme temperatures and mean numbers of days when temperatures are 32°F and 0°F and below.

TABLE 5-32

EXTREME TEMPERATURES AT NOME

J	F	M	A	M	J	J	A	S	O	N	D
Absolute maximum temperature °F											
36	47	38	42	75	79	86	79	65	55	37	43
Absolute minimum temperature °F											
-40*	-42	-46	-30	-2	25	32	27	15	-10	-24	-34

* -47°F in January 1919.

TABLE 5-33

MONTHLY VARIATION IN FREEZING TEMPERATURES AT NOME

J	F	M	A	M	J	J	A	S	O	N	D
Mean number of days maximum temperature 32°F and below											
30	27	30	23	5	0	0	0	0.5	12	26	27
Mean number of days minimum temperature 32°F and below											
31	28	31	30	24	4	0.5	2	13	25	30	31
Mean number of days minimum temperature 0°F and below											
18	18	17	9	1	0	0	0	0	0.5	8	16

5.6.4 Biota Distribution

Avifauna(3)

The Nome coastal region is classified as a major migration route for waterfowl and sea birds. The principal locations for birds are Safety Sound (Cape Nome), Sinuk River and coastal region between Cape Rodney and Cape Douglas. Sledge Island is a sea bird colony where approximately twenty-five species of sea birds reside during the warmer months.

Aerial surveys indicate an average population of 60 ducks per sq. mi. of suitable habitat in the Nome area. The average population of about 231,000 annually contributes to a fall flight of 416,000 ducks. Greater scaups and pintails are the most common ducks in the area. A small population of emperor geese, white-fronted geese and black brant are also present.

Marine Mammals(3)(4)

Distribution and abundance of maritime mammals, i.e., seals, walrus, and whales in the Nome area are closely correlated with ice and climatic conditions, ocean current patterns, and bottom type. The affinity or association with the sea ice varies between species and also seasonally. Mammals that regularly come in contact with sea ice include polar bear, walrus, bearded seal, ringed seal, harbor seal, beluga whale, bowhead whale, ribbon seal and narwhal.

Ringed Seals - Ringed seals are the most important marine mammals to the coastal residents. Distribution and movement patterns are similar to that of walruses and bearded seals. The ringed seal has a close affinity to ice and moves seasonally with the ice. In late winter and early spring, it is the most abundant seal in the shore fast ice. In summer, they inhabit the entire edge of the polar ice pack, regardless of water depth, and penetrate the ice pack to some extent.

Harbor or Spotted Seals - Two forms of harbor seals exist in Alaska waters, the land-breeding and ice-breeding types. The ice-breeding type only occurs in arctic waters.

The ice-breeding harbor seal, like the ribbon seal, is only seasonally dependent on ice. It is distributed along the south edge of the sea ice in late winter, primarily in the Bering Sea, and moves north in summer to inhabit the entire ice-free coast. The harbor seal replaces the ringed seal in the near shore environment when ice is absent. In summer they move from the Bering Sea and concentrate in bays, at mouths of major rivers and estuaries.

Bearded Seals - This seal occurs anywhere that sea ice conditions are favorable and the water is shallow. Areas of continuous opening in the sea ice created by winds and currents and areas of drifting ice floes are preferred habitat. The bearded seal is common in areas of walrus habitation.

Pacific Walrus - The walrus occurs seasonally in arctic waters. In late summer and early fall, walruses occur with bearded seals along the edge of the ice pack. Walruses winter almost entirely in the Bering Sea and migrate northward with the retreating ice in spring and summer. The formation of seasonal sea ice in early October initiates a reverse migration.

Whales - Eleven species of whales may inhabit the waters of Norton Sound depending upon the season. The most dominant whales are the bowhead and beluga whales. They inhabit the floating ice regions of the Sound from late April to mid-October. In the spring the beluga and bowhead penetrate into the seasonal ice as it becomes unstable and disintegrates.

Other marine mammals - Other marine mammals inhabiting the area include the little piked whale, northern fur seal, ribbon seal, Steller sea lion and narwhal.

Fish

The distribution of fish is drastically influenced by the presence or absence of ice. Open water occurs from May to November and fish populations are diverse at this time. During the relatively short, ice-free summer, virtually every available aquatic habitat is utilized. These include the coastal offshore waters, the brackish estuaries and river mouths, mountain streams and rivers, spring streams, tundra or foothill streams and tundra lakes and ponds.

Driftwood

A number of rivers, including the Yukon River, empty into Norton Sound. Apparently, seasonal flooding causes substantial wood debris to be carried out to the Sound since it is reported that driftwood is found on all shores of Norton Sound.(1) The coastal area is devoid of large trees. A grounded cargo ship on the northeast shore of Sledge Island apparently contributes debris to the coastal waters due to action of waves and ice.

5.6.5 Evaluation of Approaches to Storage and Disposal of Recovered Oil Offshore Nome

The evaluation of methods and approaches to storage and disposal presented in Section 5.4.5 (Kvichak Bay) essentially apply to offshore Nome with a few exceptions. Approaches to the shoreline in the area by deep-draft vessels are measured in miles which virtually precludes transfer of large quantities of recovered petroleum products ashore. LCM's and barges are used and, therefore, available in the Nome area for lightering. Transfer of spills up to approximately 1,000 barrels would be feasible. Table 5-34 is an estimate of the feasibility of various approaches to storage and disposal of recovered oil.

In situ burning is the preferred method of disposal, particularly in the case of large spills. Temporary storage considerations would be similar, except that the shoreline has an established road system. The low-lying coastal areas are subject to severe storm surges. The effects of surges such as that mentioned earlier which occurred in 1974 would be disastrous to any temporary storage facility near the shoreline.

Extensive mining operations around Nome might provide satisfactory sites for land disposal of recovered oil. However, the feasibility would have to be established long before the spill occurred. Local municipal dumps would be unsatisfactory for disposal of oil recovered from larger spills. Adequate land area is available near town to establish temporary storage sites and local earthmoving equipment could cope with the permafrost. Transfer off-site is not considered feasible because of distances exceeding 1,000 nautical miles to the nearest adequate terminal facilities.

Considerations relating to debris would be very similar to those discussed in Section 5.4.5 (Kvichak Bay).

TABLE 5- 34

EVALUATION OF APPROACHES TO STORAGE AND DISPOSAL ALTERNATIVES AT OFFSHORE NOME

Type of Product And Spill Size	In situ Burning		Immediate Storage Available		Temporary Storage In Portable Containers		Controlled Burning		Incineration		Landfill		Reprocess or use Directly		Transfer Off-Site	
	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
CRUDE OIL																
100 barrels	X		X		X		X		X		X			X		X
1,000 barrels	X		X		X		X		X		X			X		X
10,000 barrels	X			X	X		X		X			X		X		X
50,000 barrels	X			X		X	X			X		X		X		X
RESIDUAL FUEL OIL																
100 barrels		X	X		X		X		X		X			X		X
1,000 barrels		X	X		X		X		X		X			X		X
10,000 barrels		X		X	X		X		X			X		X		X
50,000 barrels		X		X		X	X			X		X		X		X
DISTILLATE FUEL OIL																
100 barrels	X		X		X		X		X			X		X		X
1,000 barrels	X		X		X		X		X			X		X		X
10,000 barrels	X			X	X		X		X			X		X		X
50,000 barrels	X			X		X	X		X			X		X		X
GASOLINE																
100 barrels	X		X			X	X			X		X		X		X
1,000 barrels	X		X			X	X			X		X		X		X
10,000 barrels	X			X		X	X			X		X		X		X
50,000 barrels	X			X		X	X			X		X		X		X

5.6 REFERENCES CITED

1. U.S. Department of Commerce, Coast and Geodetic Survey, United States Coast Pilot #9 - Pacific and Arctic Coasts, seventh edition, 1964.

2. U.S. Department of Commerce, NOAA Local Climatological Data - Annual Summary with Comparative Data, Nome, Alaska, 1972.

3. Alaska Department of Fish and Game, "Alaska's Wildlife and Habitat," State of Alaska, 1973.

4. Arctic Institute of North America - The Alaskan Arctic Coast - A Background Study of Available Knowledge, prepared for Alaska district, Corps of Engineers, Anchorage, Alaska, 1974.

5.7 OFFSHORE PRUDHOE BAY

5.7.1 Shoreline Characteristics[1,2]

The coast in the vicinity of Prudhoe Bay is generally a narrow transition zone between the tundra surface and the sea. The area is shown in Figure 5.7. Common coastal land features include beaches, barrier islands, barrier bans, spits, dunes, and river deltas. Breaks in the coast, called "windows," occur where streams, rivers, and lakes have been intersected by the sea. During the short summer, when sea ice moves off the coast, thermal and wave erosion form steep sea cliffs and a marked annual retreat of shorelines occurs.

Several small barren islands such as Gull, Midway, Crass and Return are 5 to 15 miles offshore. The Bay is shallow across most of its entrance. On the east side of the entrance the delta of the Sagaranirktok River extends for about 9 miles to Foggy Island. The waters off the delta are extremely shallow.

The coastal plain sediments are dominantly of marine origin. These sediments are composed of marine and nonmarine gravel, sand, silt and clay. In the summer the mainland forms near the coast consist mainly of marshes, small lakes and patterns produced by permafrost and frost action such as polygonal ground, thaw lakes and pingos.

5.7.2 Oceanographic Conditions

Tide Ranges

The tidal range near Prudhoe Bay is of very low amplitude. The associated tidal currents are weak also. Table 5-35 shows the tidal ranges for Flaxman Island and Barter Island, the nearest stations to Prudhoe Bay that have tidal information.

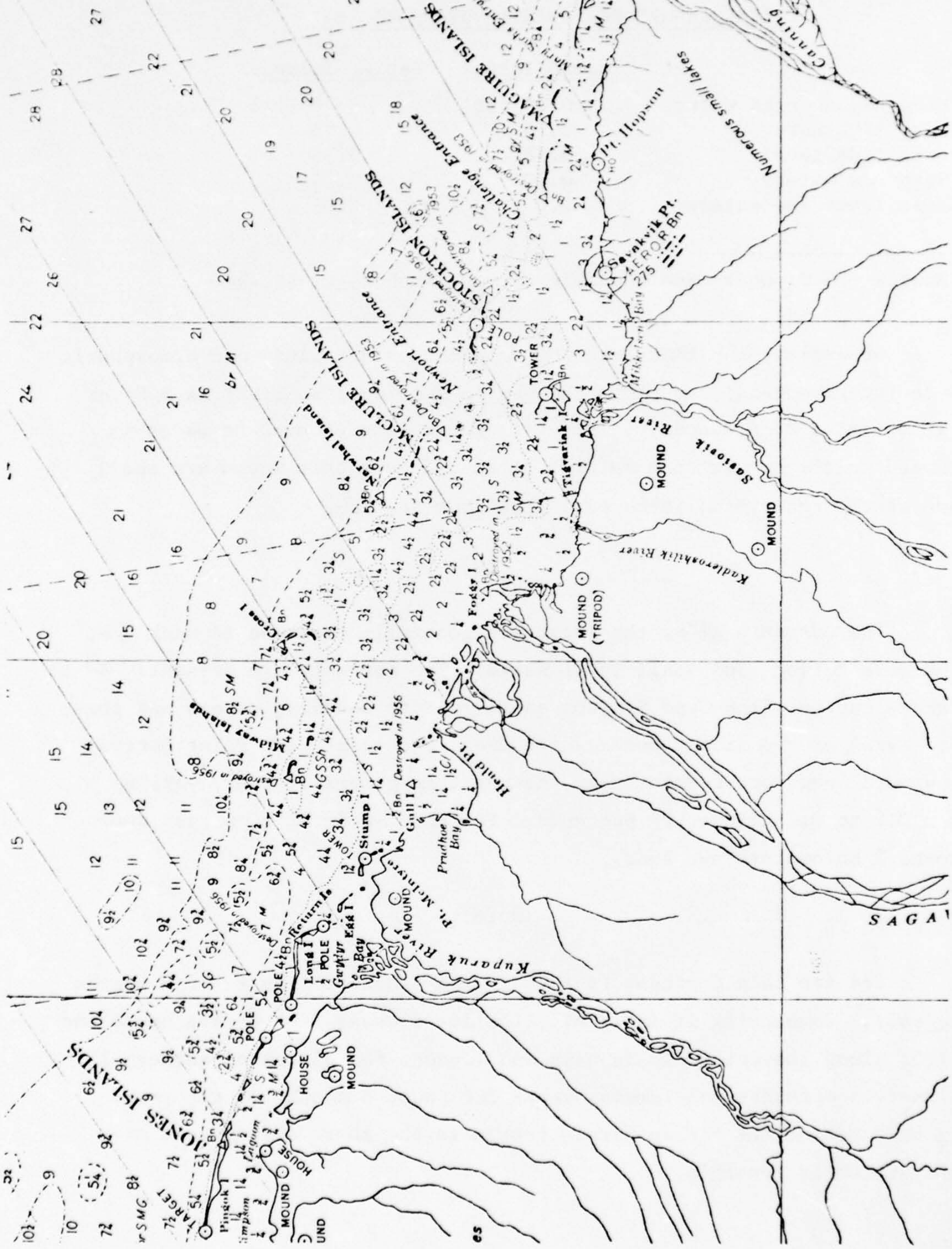

FIGURE 5-7. PRUDHOE BAY (from C.&G.S. Chart 9403)

TABLE 5-35

TIDAL RANGES FOR COASTAL BEAUFORT SEA

	Flaxman Island	Barter Island
Mean higher high waters	0.80 (ft)	0.70 (ft)
Mean high water	0.70	0.60
Half tide level	0.40	0.35
Mean low waters	0.10	0.10
Mean lower low waters	0.0	0.0

Source - U.S. Coast and Geodetic Survey, Anchorage, Alaska

Generally, the tides are not important since winds and atmospheric pressure (storm surges) can cause changes in sea level as great as 3 ft or more in a period of a few days. However, generation of surface waves is restricted to the summer open-water months, and even then waves are small because of the restricted fetch resulting from sea ice.

Currents[2]

The currents along the coast are generally weak due to pack ice, limited wave action, and small total range. Two currents are present. A long shore current from Cape Simpson eastward into Canadian waters and the Pacific Gyral of the Arctic Ocean which meets the coast near Point Barrow. The eastward longshore current near the coast is generally weak, varying between 0.2 to 0.7 kilometers per hour. The Pacific Gyral's current speed is around 2 kilometers per hour.

Ice[2][6]

Sea ice is a dominant feature in the Beaufort Seas for 7-9 months of the year. Commencing in late fall, the ice freezes fast to the beach and sea floor along the coast and in bays and lagoons for distances between 10 - 30 kilometers offshore and remains there for about 8 months of the year. During this period the ice is firmly frozen to the shore and no wave or current action is possible.

Seaward of the fast ice is a relatively narrow shear zone, the boundary between the fast ice and the seasonal pack ice zone. Beyond the seasonal pack ice lies the polar pack ice, consisting predominantly of thick multi-year floes, which are surrounded in the summer by open water or thin ice and in the winter by first-year ice.

Ice conditions vary from one year to the next. In a year in which strong fall storms force the big multi-year floes of the polar pack shoreward. This seasonal ice is easily broken up and pushed into large pressure ridges and ground-up consolidated masses of ice.

Starting with the river breakup in late May or early June, the fast ice fused to the sea floor in shallow regions thins and lifts off the bottom. The fast ice becomes thinner and weaker, but remains intact until about the middle of July when winds and/or currents break it up. After breakup the concentration of ice in coastal waters depends mostly on wind direction. Offshore winds tend to hold the ice away from shore, whereas onshore winds move it toward the shore. Ice conditions during the open season, which lasts until October, vary considerably from year to year, even from week to week. However, in the average year, there is so much ice on the shelf during the open season that it has to be considered in planning of any offshore activity.

5.7.3 Climatology

General Climate

The coastal regions of the "North Slope" are classified as arctic maritime. The general climatic conditions are characterized by cold temperatures (both winter and summer), small annual precipitation, and strong winds. The summers are characterized by cool easterly maritime winds, extensive cloudiness, fog, light precipitation or drizzle and continuous sunlight. In winter cloudiness decreases, darkness and cold temperatures prevail, and very cold winds occur. Wind chill factors can be -60°F and lower.

Significant Weather Elements

Snow - Based on data from Barter Island[3] snow has occurred in all months of the year. The seasonal snowfall has varied from 22 to 115 in. since 1949. Table 5-36 shows the maximum snowfall in 24 hours, and the mean number of days snowfall has exceeded one inch or more.

TABLE 5-36

SNOWFALL STATISTICS FROM BARTER ISLAND

J	F	M	A	M	J	J	A	S	O	N	D
Maximum snowfall in 24 hrs (in.)											
14.8	3.8	5.5	4.4	7.6	5.1	2.2	3.4	17.0	16.0	5.0	5.
Mean number of days with snowfall one inch or more											
2	1	1	1	1	0.5	0.5	1	2	3	2	1

Wind - One of the most significant features of surface wind in the arctic coastal region is the persistence factor; a calm condition along the coast prevails between 0.3 and 6% of the time. Winds usually prevail from the east but west winds may persist at times.

Monthly mean winds range 10 to 13 knots and speeds up to 70 knots have been observed at Barter Island. These persistent and occasionally high winds result in serious operational problems due to shifting snowdrifts, low visibility in blowing snow and hazardous wind chill factors. Table 5-37 shows the percentage frequency of wind speeds equal or greater than 17 and 28 knots at Barter Island. Winds at Barter Island may be slightly higher than Prudhoe Bay due to topographic convergence created by the Brooks Range.[4]

TABLE 5-37

PERCENTAGE FREQUENCY OF STRONG WINDS AT BARTER ISLAND

J	F	M	A	M	J	J	A	S	O	N	D
% Frequency wind speed $\geq$ 17 knots											
23.3	24.2	21.0	16.9	15.6	9.8	7.8	15.0	20.6	31.3	26.7	24.0
% Frequency wind speed $\geq$ 28 knots											
8.0	7.7	4.6	3.1	1.9	0.2	0.1	1.8	3.3	9.0	7.0	5.9

Temperature - Mean annual temperature around Prudhoe Bay is 10°F Freezing temperatures are reached during all months of the year. Diurnal temperature ranges are confined within relatively narrow limits varying between 8 and 17°F. Temperatures along the arctic coast are modified by the surrounding ocean even during the winter with the ocean frozen.

Table 5-38 presents the extreme temperatures for each month at Prudhoe Bay based on limited data.

TABLE 5-38

EXTREME TEMPERATURES AT PRUDHOE BAY

J	F	M	A	M	J	J	A	S	O	N	D
Absolute maximum temperature (°F)											
32	24	8	20	47	58	75	68	53	37	26	34
Absolute minimum temperature (°F)											
-48	-58	-52	-34	-18	24	30	27	15	-23	-36	-49

The persistence of cold temperatures is illustrated by Table 5-39 which shows the mean number of days that temperatures are 32°F or below.

TABLE 5-39

MONTHLY VARIATION OF FREEZING TEMPERATURES AT BARTER ISLAND

J	F	M	A	M	J	J	A	S	O	N	D
Mean number of days maximum temperature 32°F and below											
31	28	31	29	24	4	0.5	1	11	29	30	31
Mean number of days minimum temperature 32°F and below											
31	28	31	30	31	23	9	11	25	31	30	31
Mean number of days minimum temperature 0°F and below											
29	2	30	23	3	0	0	0	0	7	20	29

Vertical distribution of temperature is very consistent. A temperature inversion almost always exists but when it does disappear it usually reforms again. Wind chill factors below zero are relatively common on the North Slope and during wintertime chill factors of -30°F may be expected around 50% of the time.(5)

5.7.4 Biota Distribution

Avifauna[6]

The Alaskan arctic coastal area is inhabited by approximately 105 bird species most of which are summer migrants. The dominant species are aquatic and semiaquatic birds, such as geese, ducks, cranes, swans, shore birds, sea birds, and gulls. The majority of the land area is important nesting habitat, and the near shore waters are utilized heavily by waterfowl and other aquatic birds. Most birds occur locally only from May through September and travel the continental and international flyways. Winter residents number only 8 or 9 species.

The area serves as a major migration route and refuge for millions of birds breeding both in the area and in the Canadian Arctic. The coastal plain and the coastal areas are important breeding grounds.

Population estimates of the bird fauna are incomplete. Recent surveys of the coastal plain, excluding the western foothills, indicate minimum pre-breeding populations of 11 million birds. Table 5-40 is based on recent surveys of the major bird groups along the arctic coast.

TABLE 5-40

POPULATION OF MAJOR BIRD GROUPS ALONG ARCTIC COASTAL REGIONS

Whistling Swans	3,000 to 5,000
Geese white-fronted geese, Canada geese, black brant* snow geese.	170,000 (fluctates considerably in numbers)
Dabbling ducks . . . . pintails, widgeon, green- winged teal, mallards, shovelers	200,000 to 500,000
Diving ducks oldsquaws, eiders, scaup, scoters	875,000
Sea birds (nesting) murres, kittiwakes, puffins glaucous gulls, cormorants, guillemots	1,000,00 to 2,000,000
Ptarmigan	240,000 (varys considerably)
Shorebirds	5,500,000
Jaegers	200,000
Gulls	75,000
Terns	150,000
Raptors	14,000
Passerine birds	2,750,000

The bird populations of the coastal plain are dominated by waterfowl and shore bird species that are closely associated with freshwater or coastal marine environments. Aquatic and semiaquatic birds achieve the highest densities in the extensive low marshy areas. The highest density for waterfowl occur 80 to 96 kilometers inland from the coast.

An average summer population of approximately 1,400 birds of many species per square mile have been observed between Prudhoe Bay and Canada. Waterfowl (ducks) densities in the inshore waters (within five miles of the coast) range from 107 to 1,375 ducks per square mile with a mean density of 435 ducks per square mile. A significant breeding colony of snow geese is located at the delta of the Sagavanirktok River near Prudhoe Bay.

Marine Mammals[6]

Ringed Seal - Ringed seals, the smallest of northern seals, are the most important marine mammals to the coastal residents. The ringed seal has a close affinity to ice and moves seasonally with the ice. In late winter and early spring, it is the most abundant seal in the shore fast ice. In summer, they inhabit the entire edge of the polar ice pack, regardless of water depth, and penetrate the ice pack to some extent. Density of ringed seals is high in the coastal water of Prudhoe Bay.

Pacific Walrus - The Pacific Walrus occurs seasonally in arctic waters and is found primarily west of Barrow in the Chukchi Sea; however, some frequent the Beaufort Sea. Distribution is not known near Prudhoe Bay.

Bearded Seal - The bearded seal occurs anywhere that sea ice conditions are favorable and the water is shallow. Areas of continuous openings in the sea ice created by winds and currents and areas of drifting ice floes are preferred habitat. Density of bearded seals in the Beaufort Sea is generally light.

Whales - The bowhead, beluga, gray, humpback, finback and other whales occur seasonally in open areas of the Beaufort Sea. The bowhead and beluga are more common since they can tolerate ice-covered areas of the ocean.

Fish[6]

The fish inhabiting the freshwater and marine environment of the arctic coastal area are relatively few in number and little is known of their distribution or abundance. Approximately 23 freshwater and anadromous and 69 marine species have been identified. The freshwater fishes occupy various habitats and demonstrate varying migration patterns. Sixteen species of freshwater fish also seasonally inhabit the marine or waters of the coast. The distribution and activities of the freshwater and anadromous fishes are drastically influenced by the presence or absence of ice.

Small Land Mammals

See discussion under Umiat (Section 5.5.3)

5.7.5 Evaluation of Approaches to Storage and Disposal of Recovered Oil from Offshore Prudhoe Bay

The discussion in Section 5.4.5 (Kvichak Bay) essentially apply to offshore Prudhoe Bay. The most notable difference is felt to be the availability of well-developed facilities on shore associated with petroleum production. Transfer of recovered products between the spill site and shoreline will be extremely difficult due to the shallow waters extending miles offshore and the presence of shorefast and/or sea ice during approximately nine months of the year. Winter darkness at the high latitude will severely hamper all winter operations. Table 5-41 is an estimate of the feasibility of various approaches to storage and disposal of recovered oil.

The preferred method of disposal is in situ burning if the products are combustible and safety considerations permit uncontrolled burning. Controlled on-site burning is the second choice because the logistics of transfer to shore virtually preclude transfer of large quantities of oil across the sea ice existing nine months of the year. It is assumed that the equipment and facilities of the petroleum industry at Prudhoe Bay would be available for storage and disposal. The Trans-Alaska Pipeline access road could be used to transport small quantities (100-200 barrels) to metropolitan areas for disposal. However, incineration onshore would be more cost-effective.

The primary sources of debris offshore Prudhoe Bay is expected to be snow, ice, and dead birds. All disposal of debris would normally be by incineration in the immediate area. Little or no driftwood or sources of industrial pollution exist along the arctic coast.

TABLE 5-41

EVALUATION OF APPROACHES TO STORAGE AND DISPOSAL ALTERNATIVES

AT OFFSHORE PRUDHOE BAY

Type of Product And Spill Size	In situ Burning		Immediate Storage Available		Temporary Storage In Portable Containers		Controlled Burning		Incineration		Landfill		Reprocess or use Directly		Transfer Off-Site	
	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
CRUDE OIL																
100 barrels	X		X		X		X		X		X		X			X
1,000 barrels	X		X		X		X		X			X	X			X
10,000 barrels	X		X		X		X		X			X	X			X
50,000 barrels	X		X		X		X		X			X	X			X
RESIDUAL FUEL OIL																
100 barrels		X	X		X		X		X		X			X		X
1,000 barrels		X	X		X		X		X			X		X		X
10,000 barrels		X	X		X		X		X			X		X		X
50,000 barrels		X	X		X		X		X			X		X		X
DISTILLATE FUEL OIL																
100 barrels	X		X		X		X		X			X	X			X
1,000 barrels	X		X		X		X		X			X	X			X
10,000 barrels	X		X		X		X		X			X	X			X
50,000 barrels	X		X		X		X		X			X	X			X
GASOLINE																
100 barrels	X			X		X	X			X		X		X		X
1,000 barrels	X			X		X	X			X		X		X		X
10,000 barrels	X			X		X	X			X		X		X		X
50,000 barrels	X			X		X	X			X		X		X		X

5.7 REFERENCES CITED

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3. U.S. Department of Commerce, NOAA, Local Climatological Data - Annual Summary with Comparative Data, Barter Island, Alaska, 1972.

4. Dickey, W. W., "A Study of a Topographic Effect on Wind in the Arctic," Journal of Meteorology, vol. 18, pp. 790-803, 1961.

5. Searby, H. W. and Hunter, M., "Climate of the North Slope - Alaska" NOAA Technical Memorandum NWS AR-4, Alaska Region, Anchorage, Alaska, 1971.

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APPENDIX A

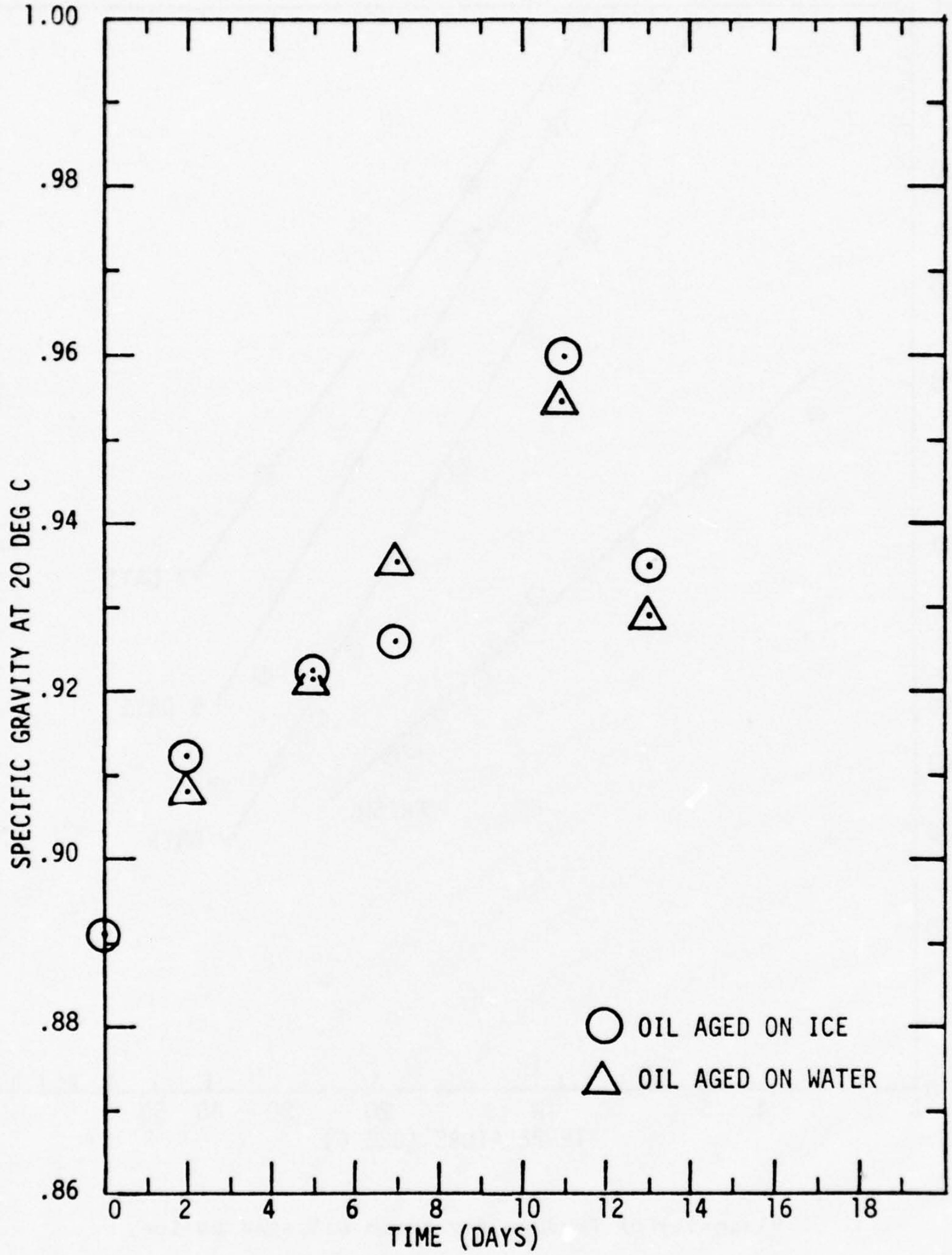
PETROLEUM PROPERTIES

- Characteristics of some Cook Inlet oils

Item	Field	Productive formation[1]	Depth, feet	Gravity, ° API	Color[2]	Viscosity at 100° F SUS[3]	Pour point, ° F	Sulfur, weight-percent	Nitrogen, weight-percent	Carbon residue, weight-percent[4]	Ratio, nitrogen to carbon residue	Distillation yields, volume-percent: Frac. 1-3 (light gasoline)	Frac. 4-7 (naphtha)	Frac. 8-12 (kerosine, gas-oil)	Frac. 13-15 (lubricating oil)	Residuum
1	Cook Inlet, N......	Middle Ground Shoal, cgl.	10,927	53.7	D.G.	29	<5	0.00	0.005	0.1	0.050	29.6	39.4	21.4	5.0	1.7
2	Granite Point......	Middle Ground Shoal, ss..	8,650	42.8	B.G.	34	<5	.02	.039	1.1	.035	17.7	27.4	24.4	13.5	14.4
3	Granite Point......	Middle Ground Shoal, ss..	8,181	40.9	B.G.	34	<5	.05	.054	1.8	.030	15.7	26.8	23.3	13.7	16.2
4	McArthur River.....	Hemlock, cgl............	9,370	33.0	B.G.	45	35	.09	.146	4.3	.034	8.6	21.0	26.3	16.0	27.4
5	McArthur River.....	Hemlock, cgl............	10,662	33.4	G.B.	45	<5	.07	.156	5.1	.031	9.9	20.7	22.0	15.8	29.1
6	McArthur River.....	Hemlock, cgl............	9,486	32.7	B.B.	45	5	.09	.142	4.8	.030	7.6	19.6	26.8	16.5	27.6
7	McArthur River.....	Hemlock, cgl............	10,660	34.2	B.B.	37	20	.08	.132	4.2	.031	8.8	20.6	24.3	15.6	28.6
8	McArthur River.....	Tyonek, cgl.............	11,349	33.0	G.B.	47	35	.11	.149	1.1	.044	6.5	21.1	26.0	18.3	26.4
9	McArthur River.....	West Foreland, ss........	11,350	30.6	B.B.	59	<5	.15	.186	6.8	.027	6.7	19.2	21.9	16.8	31.0
10	Middle Ground Shoal	Middle Ground Shoal, cgl.	8,400	33.8	G.B.	44	<5	.06	.124	4.0	.031	10.1	21.2	26.2	15.6	25.3
11	Middle Ground Shoal	Hemlock, cgl............	7,483	35.0	G.B.	40	<5	.05	.115	3.5	.033	9.1	21.1	26.0	16.2	25.1
12	Redoubt Shoal......	Hemlock, cgl............	10,000	27.7	B.B.	100	10	.22	.211	8.4	.025	8.6	12.7	21.9	15.7	37.5
13	Swanson River......	Hemlock, cgl............	11,000	29.7	B.B.	61	<5	.16	.203	8.1	.025	7.7	19.7	24.9	16.3	31.4
14	Swanson River......	Hemlock, cgl............	10,900	33.8	G.B.	46	10	.05	.133	4.0	.033	12.5	17.8	24.6	15.0	27.8
15	Swanson River......	Hemlock, cgl............	11,200	30.2	G.B.	65	15	.08	.161	7.4	.022	11.2	14.3	24.6	14.6	32.9
16	Swanson River......	Hemlock, cgl............	11,000	33.4	G.B.	46	10	.05	.133	3.4	.039	9.2	19.8	23.5	16.3	29.1
17	Swanson River......	Hemlock, cgl............	11,000	36.0	G.B.	40	<5	.03	.095	4.3	.022	10.7	23.5	23.6	15.4	24.8
18	Trading Bay........	Middle Ground Shoal, ss..	5,363	31.0	B.B.	53	<5	.05	.149	4.3	.035	9.7	18.8	23.4	16.0	30.5
19	Trading Bay........	Hemlock, cgl............	10,500	32.3	B.G.	45	20	.11	.026	4.7	.028	3.9	25.1	31.1	17.7	26.2

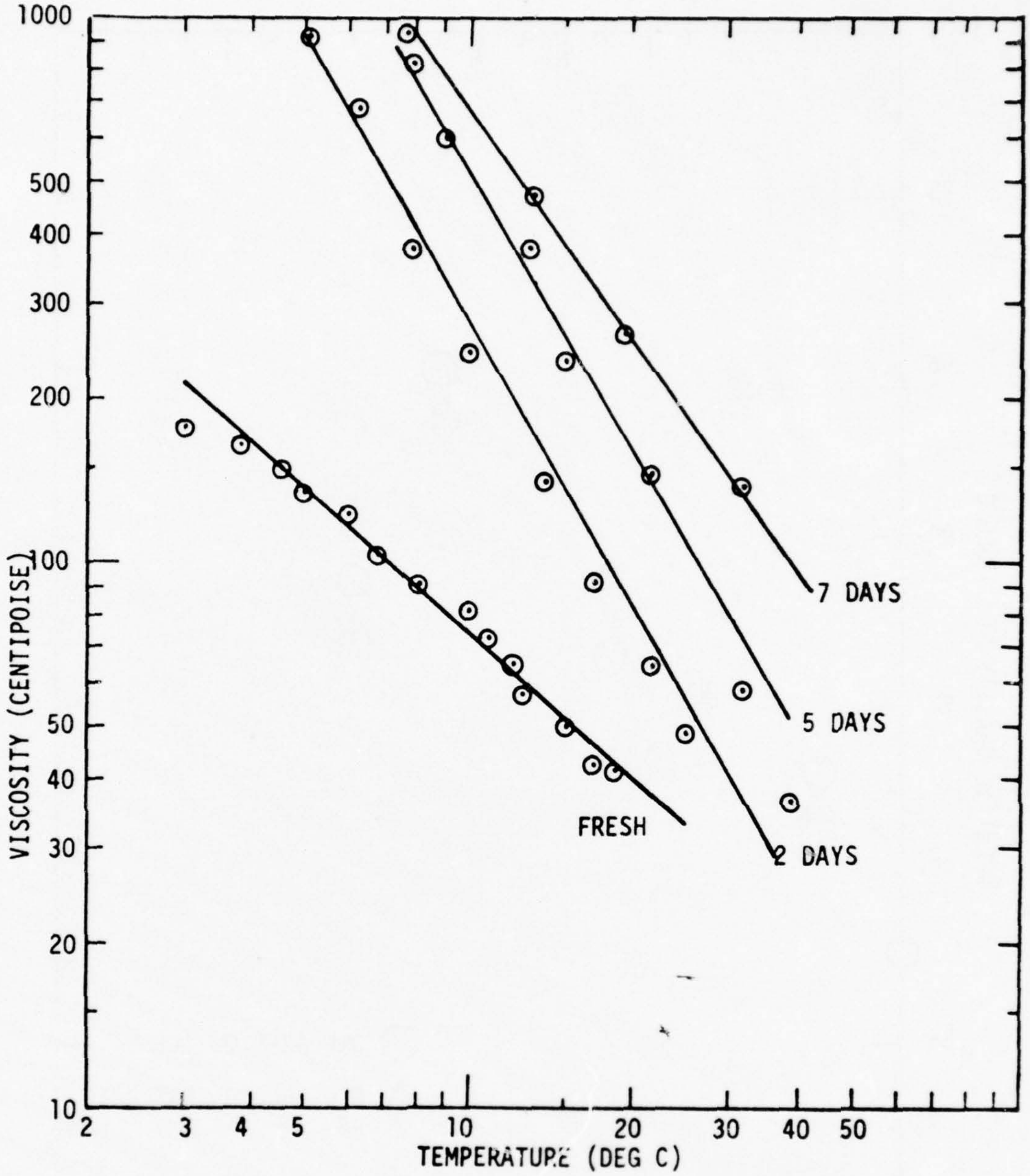
[1]Abbreviation: cgl. = conglomerate; ss. = sandstone.
[2]Colors are designated as follows: D.G. = dark green; B.G. = brownish green; G.B. = greenish black; B.B. = brownish black.
[3]SUS = Saybolt Universal Seconds.
[4]Carbon residue values are equivalent to those obtained by the Conradson method, ASTM designation D189-46.

Source: "Oilfields and Crude Oil Characteristics, Cook Inlet Basin, Alaska," U.S. Bureau of Mines Report of Investigations/1972, No. RI 7688.



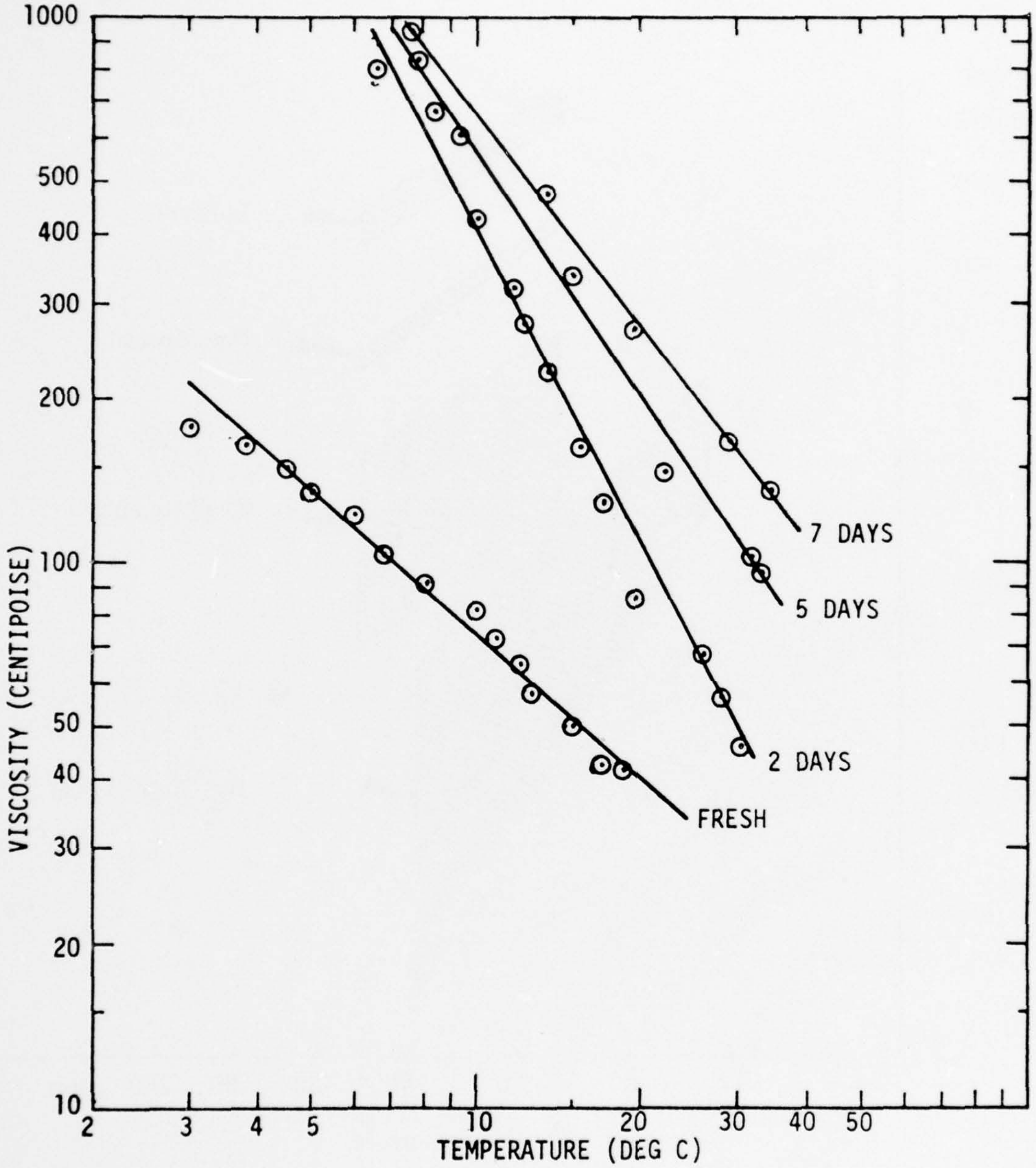
Specific gravity of aged Prudhoe Bay crude oil.

Source: John L. Glaeser, and George P. Vance, "A Study of the Behavior of Oil Spills in the Arctic," Final Report of U.S. Coast Guard Project Number 714108/A/001,002, February 1971.



Viscosity of Prudhoe Bay crude oil aged on ice.

Source: John L. Glaeser, and George P. Vance, "A Study of the Behavior of Oil Spills in the Arctic," Final Report of U.S. Coast Guard Project Number 714108/A/001,002, February 1971.



Viscosity of Prudhoe Bay crude oil aged on water.

Source: John L. Glaeser, and George P. Vance, "A Study of the Behavior of Oil Spills in the Arctic," Final Report of U.S. Coast Guard Project Number 714108/A/001,002, February 1971.

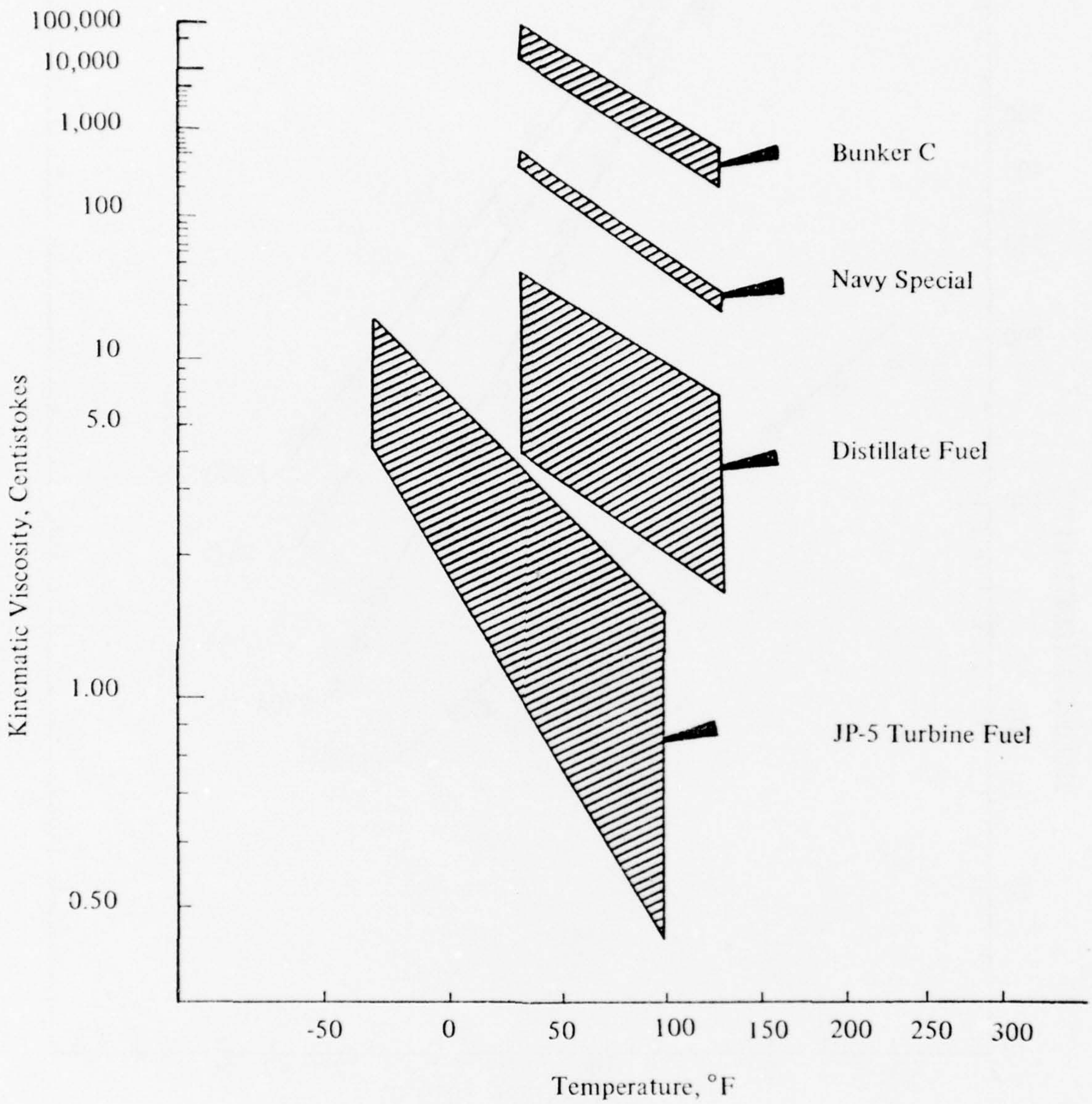


Figure 1 Range of Viscosity Versus Temperature For Bunker C, Navy Special, Distillate Fuel, and JP-5 Turbine Fuel

Source: "Study of Equipment and Methods for Removing or Dispersing Oil from Open Waters," U.S. Naval Civil Engineering Laboratory, Report No. CR71.001, August 1970.

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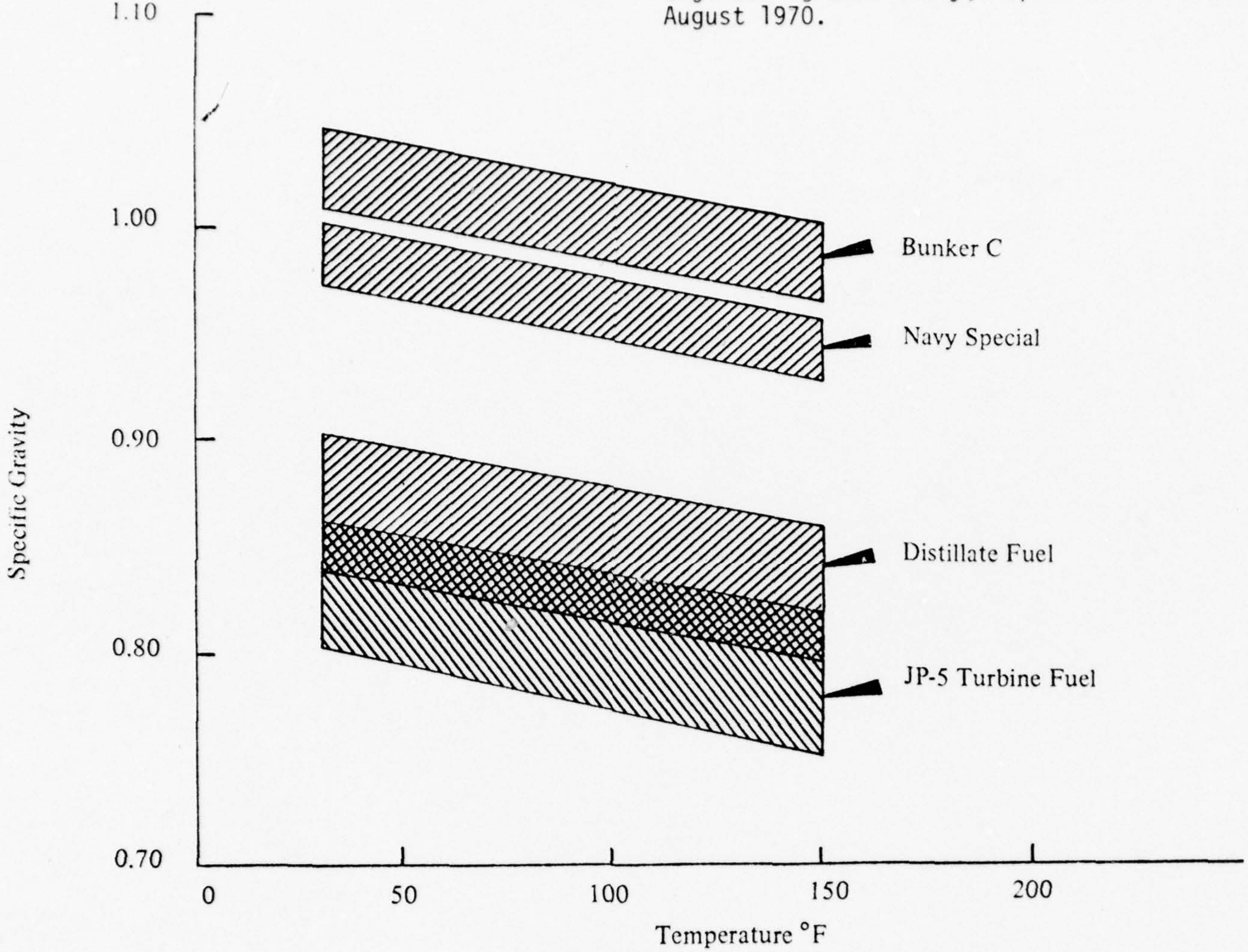
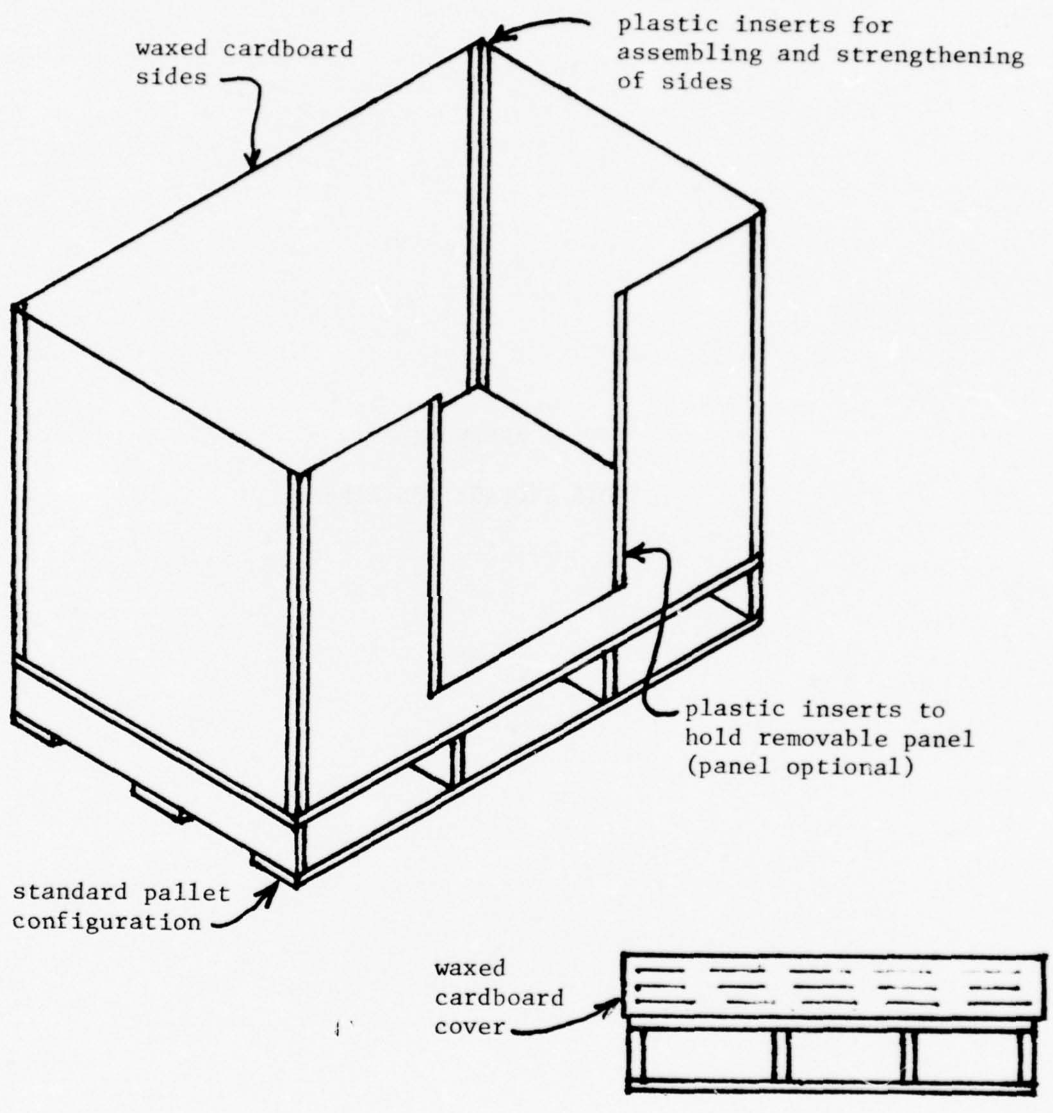


Figure 2 Range of Specific Gravities Versus Temperature For Bunker C, Navy Special, Distillate Fuel, and JP-5 Turbine Fuel

APPENDIX B

OIL STORAGE CONTAINERS



FOLDABLE WAXED CARDBOARD
CARTON FOR DEBRIS STORAGE

PILLOW TANK DIMENSIONS

NOMINAL TANK CAPACITY & DIMENSION—(SP. GR. LIQUID —

SIZE EMPTY			FILLED					APPROX. BOX SIZE
W	L	Shape	Cap.	W	L	H	A	IN. x IN. x IN.
8′-0″	10′-0″	Rectangular	1,000	6′-8″	8′-8″	3′-0″	5.5″	54 x 20 x 12
10′-0″	10′-0″	Square	1,500	8′-6″	8′-6″	3′-9″	6.4″	66 x 20 x 12
10′-0″	12′-6″	Rectangular	2,000	8′-6″	11′-0″	3′-9″	6.4″	66 x 20 x 12
10′-0″	17′-6″	Rectangular	3,000	8′-6″	16′-0″	3′-9″	6.4″	66 x 24 x 24
13′-0″	13′-0″	Square	3,000	11′-6″	11′-6″	4′-0″	3.0″	84 x 20 x 12
14′-0″	15′-0″	Rectangular	4,000	12′-7″	13′-7″	4′-0″	2.4″	90 x 22 x 14
16′-0″	16′-0″	Square	5,000	14′-7″	14′-7″	3′-11″	1.2″	102 x 22 x 14
12′-0″	26′-0″	Rectangular	6,000	10′-6″	24′-6″	3′-10″	3.8″	78 x 26 x 15
16′-0″	18′-0″	Rectangular	6,000	14′-6″	16′-6″	4′-2″	1.6″	102 x 24 x 14
18′-0″	18′-0″	Square	7,500	16′-6″	16′-6″	4′-8″	1.6″	114 x 24 x 15
12′-0″	42′-0″	Rectangular	10,000	10′-6″	40′-6″	3′-10″	3.8″	84 x 30 x 16
20′-0″	22′-0″	Rectangular	10,000	18′-6″	20′-6″	4′-3″	0.5″	132 x 26 x 15
12′-0″	50′-0″	Rectangular	12,000	10′-6″	48′-6″	3′-10″	3.8″	84 x 34 x 18
22′-0″	22′-0″	Square	12,000	20′-6″	20′-6″	4′-7″	0.5″	144 x 26 x 15
24′-0″	24′-0″	Square	15,000	22′-6″	22′-6″	5′-0″	0.6″	156 x 26 x 16
24′-0″	28′-0″	Rectangular	20,000	22′-6″	26′-6″	5′-9″	1.5″	156 x 26 x 18
24′-0″	34′-0″	Rectangular	25,000	22′-6″	32′-6″	5′-9″	1.5″	156 x 26 x 18
24′-0″	52′-0″	Rectangular	40,000	22′-6″	50′-8″	5′-9″	1.5″	156 x 30 x 22
24′-0″	65′-0″	Rectangular	50,000	22′-6″	63′-8″	5′-6″	1.1″	156 x 45 x 25
24′-0″	80′-0″	Rectangular	65,000	22′-6″	78′-8″	5′-9″	1.5″	156 x 45 x 25

Source: Manufacturer's Literature from Goodyear

Standard Uniroyal oil and fuel tanks.

Capacity (gallons)	Dimensions empty (± 6 inches)		Dimensions filled (± 6 inches)			Approx weight* (lbs)	Shipping weight (lbs)	Crate size (inside dimensions)	Shipping size (cubic feet)	Ground cloth weight (lbs)
	Width	Length	Width	Length	Height					
250	6′8″	6′8″	6′2″	6′2″	1′	25	55	3′x3′x8″	7	6
500	6′8″	9′9″	5′11″	9′	1′6″	32	62	3′x3′x8″	7	10
900	9′	10′2″	8′	9′2″	2′	41	75	4′x3′x10″	11	16
1,000	9′	11′1″	8′	10′1″	2′	44	78	4′x3′x10″	11	18
1,200	11′2″	10′	10′1″	8′11″	2′2″	49	83	4′x3′x10″	11	20
1,500	11′2″	11′2″	9′11″	9′11″	2′6″	54	97	4′x3′x1′	14	22
2,000	12′4″	12′4″	11′	11′	2′8″	63	102	4′x3′6″x1′	16	27
2,500	13′6″	13′6″	12′2″	12′2″	2′8″	74	123	4′x3′6″x1′	16	32
3,000	13′6″	15′	12′	13′6″	3′	87	141	4′6″x3′6″x1′	19	36
3,500	13′6″	17′	12′	15′6″	3′	91	145	4′6″x3′6″x1′	19	40
5,000	16′10″	16′8″	15′	14′10″	3′8″	110	170	5′x3′6″x1′	20	50
6,000	18′	17′6″	16′	15′6″	4′	122	182	5′x3′6″x1′	20	56
10,000	21′4″	22′4″	19′4″	20′4″	4′	180	258	5′x4′x1′	25	84
15,000	27′	25′1″	25′	23′1″	4′	252	333	5′x4′x1′2″	29	120
20,000	29′2″	29′10″	27′2″	27′10″	4′	325	410	5′x4′x1′4″	32	154
25,000	32′8″	32′5″	30′8″	30′5″	4′	440	528	5′x4′x1′6″	36	188
50,000	23′11″	65′	22′9″	63′9″	5′8″	780	820	5′x4′x2′	40	390
100,000	61′3″	61′9″	59′3″	59′9″	4′	1,519	1,668	7′x5′x2′	78	670

*Does not include weight of optional items.

Source: Manufacturer's Literature from Uniroyal

Sealdtanks: large transportable containers for liquids.

Length (ft)	Capacity at 5 psi (gallons)		Net weight (lbs)
	7 ft width	7 ft 4 in. width	
16	1,500	1,665	525
17	1,610	1,780	545
18	1,715	1,895	570
19	1,820	2,010	590
20	1,925	2,125	615
21	2,030	2,240	635
22	2,135	2,355	655
23	2,240	2,470	680
24	2,350	2,585	700
25	2,460	2,710	725
26	2,575	2,835	750
27	2,690	2,960	770
28	2,805	3,085	795
29	2,920	3,210	820
30	3,035	3,335	840
31	3,155	3,465	860
32	3,275	3,595	885
33	3,390	3,720	910
34	3,510	3,850	930
35	3,635	3,985	955
36	3,765	4,125	980
37	3,900	4,270	1,000
38	4,040	4,420	1,025
39	4,180	4,570	1,050

Sealdrums: easily portable containers for liquids.

Capacity (gallons)	Length	Diameter	Weight empty (lbs)
55	2′ 10½″	1′ 11½″	50
250	5′	3′ 4″	250
375	6′	3′ 8″	125
500	5′ 2″	4′ 5⅛″	285
515	6′ 8″	3′ 10″	285

Source: Manufacturer's Literature from Uniroyal

Sealdbins: portable containers for flowable solids.

Capacity (cu ft)	Height		Average diameter filled	Weight empty (lbs)	Max weight of material (per cu ft)		Filling time (minutes)	Emptying time (minutes)
	Overall	Suspended			Standard	Heavy duty		
300	8′ 3″	8′ 11″	7′ 6″	450	40	60	10 to 15	8 to 12
120	7′ 6″	8′ 1″	5′ 3″	330	100	–	7 to 8	3 to 6
70	6′ 10″	7′ 4″	4′	180	60	125	3 to 6	2 to 5
66	5′ 5″	5′ 11″	4′ 8″	170	60	175	3 to 6	2 to 5
50	5′ 8″	6′ 2″	3′ 8″	150	60	175	3 to 6	2 to 5

Filatex tanks: stationary containers for liquids.

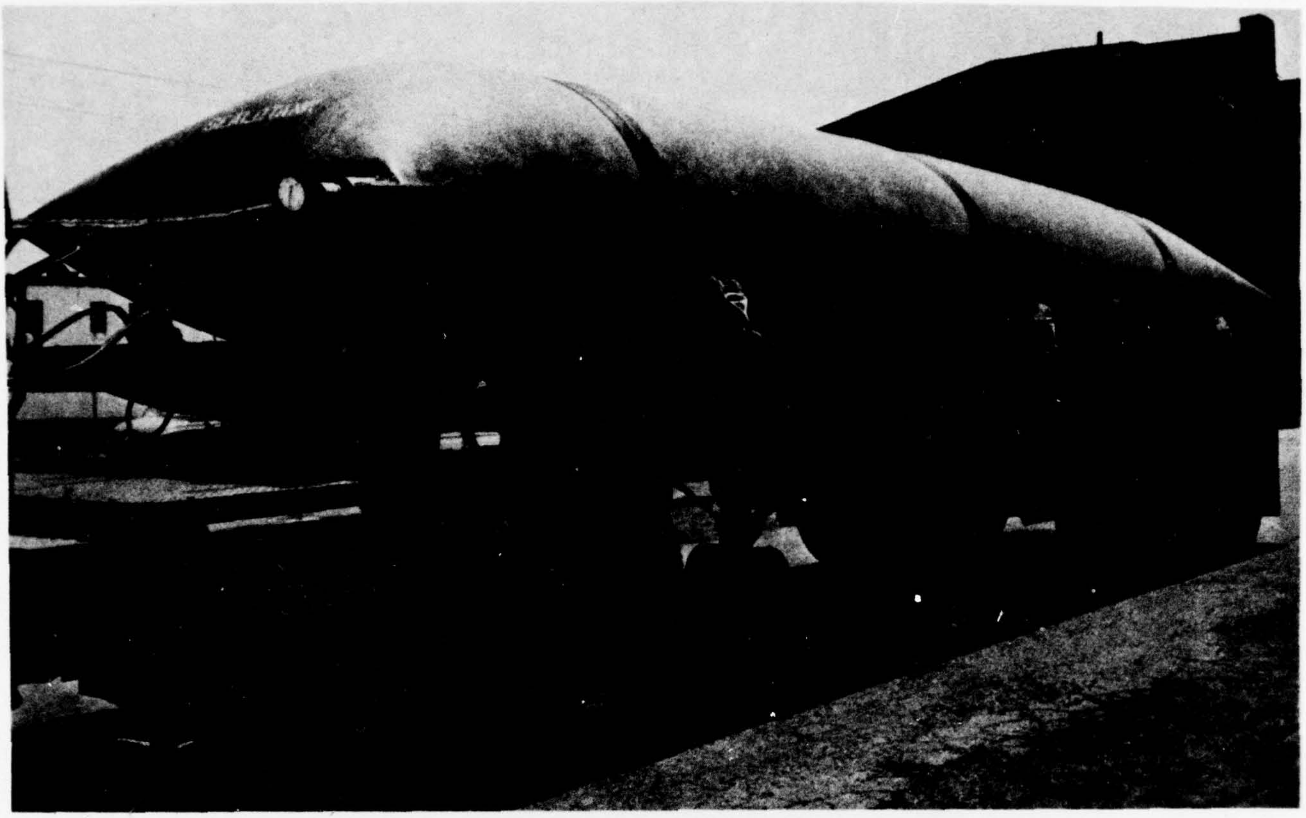
Capacity (gallons)	Dimensions empty		Dimensions filled			Dimensions rolled	Approximate weight (lbs)	Shipping weight (lbs)	Approximate shipping size (cu ft)
	Width	Length	Width	Length	Height				
500	6′ 3½″	7′ 7″	5′ 3½″	6′ 7″	2′ 6″	2′ 10″ × 2′ 5″ × 1′	63	125	13
1,000	8′ 6″	10′ 3″	7′ 6″	9′ 3″	2′ 6″	3′ 2″ × 2′ 11″ × 1′	99	175	17
1,200	8′ 6″	12′ 1″	7′ 6″	11′ 1″	2′ 6″	3′ 2″ × 3′ 2″ × 1′	114	190	18
2,500	10′ 6½″	14′	9′ 6½″	13′	3′ 6″	3′ 10″ × 3′ 4″ × 1′ 4″	155	250	28
5,000	15′ 10¾″	17′ 8″	14′ 10¾″	16′ 8″	3′ 6″	4′ 2″ × 3′ 8″ × 1′ 4″	278	415	33
6,000	17′	17′ 3″	16′	16′ 3″	4′	4′ 2″ × 3′ 8″ × 1′ 4″	290	525	33
10,000	21′ 3″	22′ 5″	20′ 3″	21′ 5″	4′	3′ 9″ × 3′ 6″ × 1′ 8″	459	615	34
15,000	24′ 9″	28′ 5″	23′ 9″	27′ 5″	4′	3′ 8″ × 3′ 2″ × 2′	746	960	35
20,000	28′ 10½″	32′ 2″	27′ 10½″	31′ 2″	4′	4′ 2″ × 3′ 8″ × 2′	979	1,245	45
25,000	33′	34′ 11″	32′	33′11″	4′	5′ × 3′ × 2′	1,210	1,625	45
50,000	40′ 1″	53′	39′ 1″	52′	4′	7′ 8″ × 4′ 8″ × 3′ 4″	2,215	2,950	153
100,000	53′ 7″	66′ 6″	52′ 7″	65′ 6″	4′	7′ 8″ × 6′ 8″ × 6′	3,703	4,800	364

Static storage tanks: stationary containers for oil products.

Capacity (gallons)	Dimensions empty		Dimensions filled			Weight (lbs)	Crate size
	Width	Length	Width	Length	Height		
1,500	8′ 9″	11′ 4″	8′ 3″	10′ 10″	3′	65	4′ × 3′ 9″ × 11″
10,000*	22′	22′	21′	21′	4′	180	7′ 11″ × 3′ × 1′
10,000†	12′ 3″	42′	10′ 10″	41′	4′	163	5′ 5″ × 4′ × 1′ 4″
25,000	23′ 11″	34′	22′ 11″	33′	5′ 8″	430	6′ × 3′ × 2′
50,000	24′	65′	22′ 6″	65′	5′ 6″	814	9′ 10″ × 4′ 6″ × 1′ 4″

*8 oz per sq yd fabric; †13 oz per sq yd fabric.

Source: Manufacturer's Literature from Uniroyal



Sizes: 1,000 to 4,570 gallons

(Flat widths 7′4″ and 7′0″)

LENGTH IN FEET	APPROX. NET WT. (LBS.)	7′0″ W. GALLONS CAPAC.*	7′4″ W. GALLONS CAPAC.*
16	525	1,500	1,665
17	545	1,610	1,780
18	570	1,715	1,895
19	590	1,820	2,010
20	615	1,925	2,125
21	635	2,030	2,240
22	655	2,135	2,355
23	680	2,240	2,470
24	700	2,350	2,585
25	725	2,460	2,700
26	750	2,575	2,815
27	770	2,690	2,930

LENGTH IN FEET	APPROX. NET WT. (LBS.)	7′0″ W. GALLONS CAPAC.*	7′4″ W. GALLONS CAPAC.*
28	795	2,805	3,045
29	820	2,920	3,160
30	840	3,035	3,275
31	860	3,155	3,390
32	885	3,275	3,505
33	910	3,390	3,620
34	930	3,510	3,735
35	955	3,635	3,850
36	980	3,765	3,965
37	1,000	3,900	4,080
38	1,025	4,040	4,195
39	1,050	4,180	4,570

*5 p.s.i. (+3%)

Source: Manufacturer's Literature from Uniroyal

APPENDIX C

SUMMARY OF ~70,000 GALLON DIESEL OIL SPILL AT PRUDHOE BAY, ALASKA IN DECEMBER 1975

Introduction

On December 17, 1975 a fuel oil spill from a tank farm at the Slope Camp near Prudhoe Bay was reported by the Alyeska Pipeline Service Company. Initial reports (subsequently cited by the press) placed the volume of the spill as high as 600,000 gallons, a figure based on the total inventory of fuel in the tanks adjacent to the one that had failed. Within one day, it was determined that the total volume of diesel fuel spilled was approximately 70,000 gallons. The final spill volume appears to be approximately 72,000 gallons.

From the nature of the present study, the sponsor (U.S. Coast Guard) deemed it appropriate to send a Battelle study team member to inspect the spill site. Observations of the cleanup and disposal procedures were to be related to the temporary storage and ultimate disposal of spills in other areas under similar conditions. The following description of the spill and ensuing cleanup and disposal operations is a summary of observations during a site inspection on December 22, interviews with personnel involved in the cleanup, and information provided by other observers at the site. The author is particularly indebted to Mr. Ray Morris, Chief of Oil Programs, Alaska Operations Office of the Environmental Protection Agency in Anchorage, Alaska for the information and on-scene observations relating to developments during the first few days following the spill. An interview with Ray Anselm, Master Mechanic at the Slope Camp, who participated throughout the cleanup, also provided significant insight into the human side of operating under winter conditions in the Arctic. The author is also indebted to Mr. George Watt, Camp Manager for Alaska General JALASKO who arranged accommodations and set-up interviews.

The exact causes of the spill, total volume lost and description of the facilities described in this summary are somewhat conjectural because no official reports have been issued by the Environmental Protection Agency or Alyeska Pipeline Service Company at the date of this writing. The spill did not reach adjacent waters. It is doubtful that the residue remaining will migrate to nearby waters during or following spring breakup.

Setting of the Spill

The spill occurred in a tank farm at the Slope Camp (formerly called SURFCOATE Camp) approximately two miles southwest of Prudhoe Bay and about 1-1/2 miles from the Sagavanirktok River. The location is shown in Figure 1, a rough sketch of the area. The group of tanks from which the diesel fuel was lost is shown diagramatically in Figure 2. The fifteen tanks were fabricated from surplus pipe sections from the Trans-Alaska Pipeline. Each tank in the farm was nominally four feet in diameter and 309 feet long. The entire group of fifteen tanks was surrounded by a low containment dike constructed of gravel. Approximately ten of the 809 foot long tanks containing diesel fuel were interconnected by a common fill and drain manifold line on one end of the tanks (each individual tank could be isolated by a valve). All were interconnected on the opposite end by a common line with a single U-tube vent pipe. The vent pipe contained a pressure relief valve and a gate valve. The gate valve was downstream* of the pressure relief valve.

Each tank had a capacity slightly exceeding 60,000 gallons when filled to 90% of total capacity. A 10% head space was specified upon filling to accomodate thermal expansion of the fuel. The fuel lost in the incident was #1 Diesel (also called Arctic Diesel).

Cause of the Spill

No individual was present when the spill occurred, so the exact time is unknown. The spill was first noted when an individual driving by the site on December 17 observed that the end of one of the tanks in the fifteen-tank array was missing. Events leading up to the release are tabulated below:

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* The gate valve was located between the relief valve and the vent line opening to the atmosphere. This valve could block the vent line and the relief valve protecting these ten tanks.

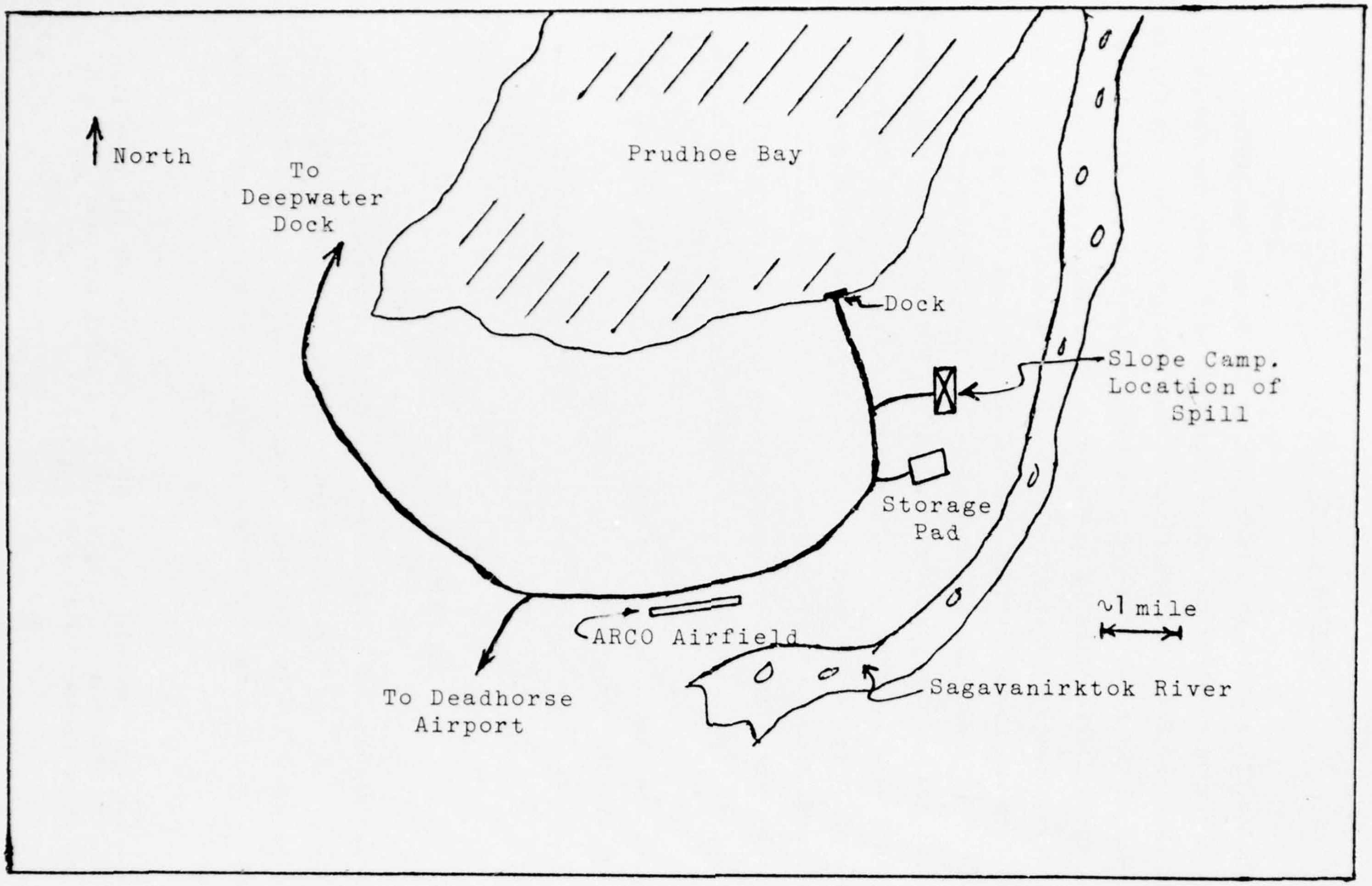

FIGURE 1. General Area Location Showing Spill Site

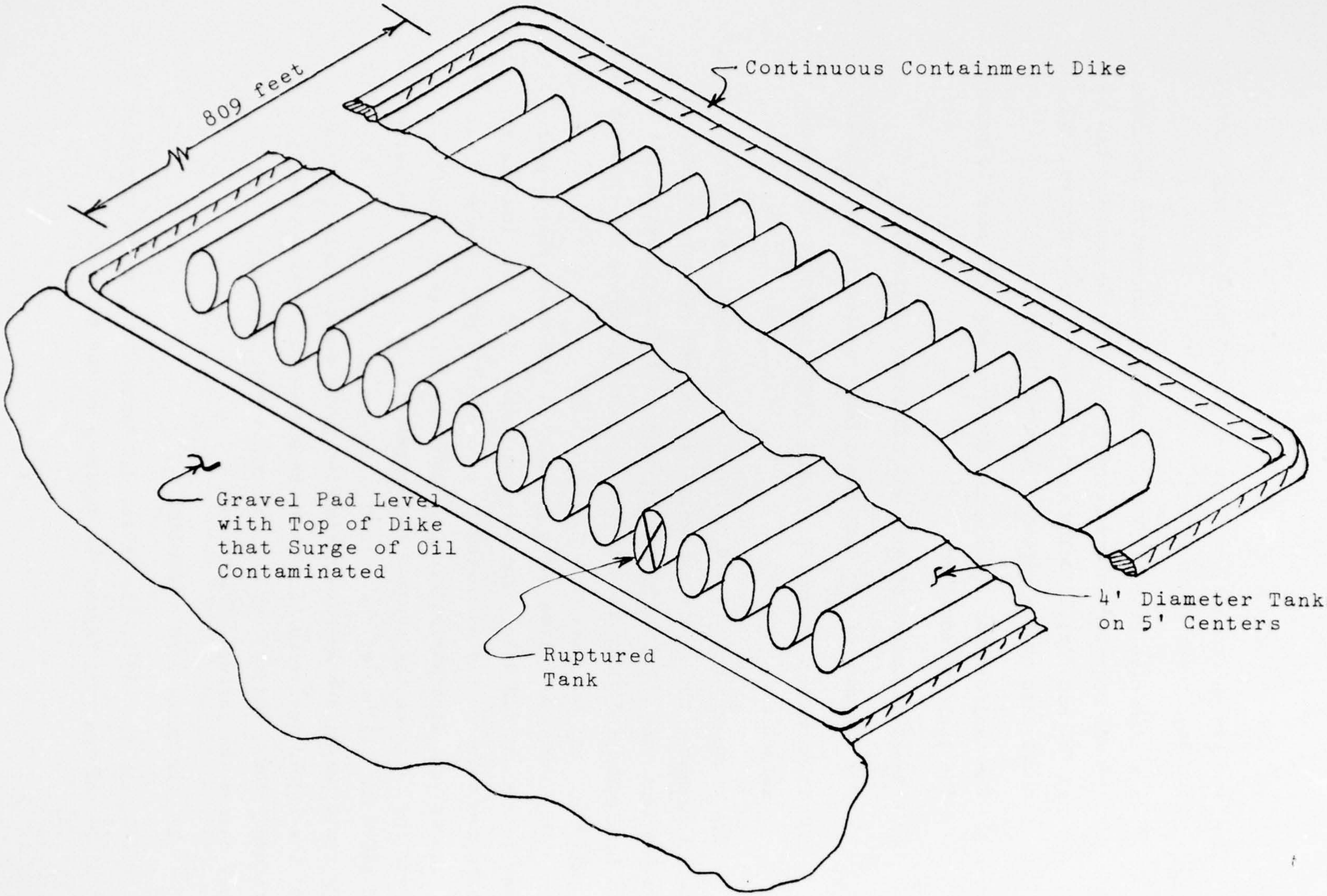

FIGURE 2. Tank Farm Layout Showing Ruptured Tank

1) the ten interconnected tanks had been topped off approximately two days prior to the spill

2) a sudden rise of 50-60°F in the ambient temperature occurred between December 16 and December 17. The temperature had been in the mid-forties below zero and rose to approximately 10° above zero over a period of several hours.

3) The manifold for filling and draining was left open to permit the tanks to equalize.

4) The exact amount of fill was not known precisely.

5) The adequacy of the tank-level gauge system is questionable.

6) There were no alarm or routine visual inspection procedures established.

The cause of the tank end failure was obviously overpressurization. A four-foot diameter flat plate was welded to the end of each cylindrical pipe in the tank farm. Following the incident, the flat plates on all of the ten interconnected tanks were dished outward, including the one that was blown completely off the tank that failed.

The common vent line had a pressure relief valve that may have been set as high as 125 psia. The pressure required to fail the end of the tanks was subsequently estimated to be under 100 psi. The gate valve in the common vent line was partially closed according to an observer who was among the first at the scene. The restriction due to the partially-closed valve and failure of the relief valve due to an excessively high setting could permit the overpressurization noted due to thermal expansion of the liquid fuel resulting from the sudden and extreme rise in temperature. Thus, the sequence of abnormal events tabulated below probably caused the failure of the tank:

1) the tanks were overfilled

2) the 50 - 60°F rise in ambient temperature caused expansion of the fuel beyond the capacity of the ten tanks.

3) a gate valve that should not have been in the vent line was left partially closed

4) a pressure relief valve that should have accommodated the pressure rise due to thermal expansion of the fuel was set too high.

Effects

The complete removal of the end plate of the tank that failed permitted complete and rapid discharge of most of the approximately 70,000 gallons of fuel. A fraction of the contents was retained because the end of the 809 foot long tank that failed was approximately two feet higher in elevation than the opposite end. The resultant surge of diesel fuel caused an estimated 2,000 gallons of the released product to overshoot the containment dike. The 2,000 gallons spread across approximately 1/2 acre of an extensive gravel pad that abutted the containment dike (see Figure 2). The gravel work pad was essentially flat and covered with several inches of compact snow at the time of the incident.

The containment dike and gravel work pad had been wet just prior to freeze-up which presented an effective ice barrier that retarded penetration into the gravel by the spilled fuel. There was snow cover throughout the area which seriously hampered efforts to determine the extent of migration of the released oil. Essentially all of the fuel that spread outside the containment dike and a substantial fraction of the remainder contained within the dike was absorbed by the snow. Some pooling occurred immediately adjacent to the ruptured tank. Very little penetration of the ground surface or face of the dike was observed.

Cleanup Methods

The cleanup was accomplished by four primary methods:

- bulldozers to push fuel-contaminated snow into piles, which were in turn removed by front loaders for disposal

- a pump (or vacuum) truck was used to recover oil that could be located in pools
- fresh snow was brought to the area for use as a sorbent
- commercial sorbents were used where the contaminated snow could not be reached by heavy machinery and where the overburden of snow had been removed.

The snow that had blown inside the containment dike was unconsolidated and acted as a sorbent of the released oil. The ambient temperatures existing during the cleanup operations did not fall below approximately -55°F. The viscosity of Arctic Diesel is relatively low (similar to water at 70°F) at temperatures to -60°F, so all fuel released remained in a completely fluid state. The oil released beneath layers of snow several inches thick did not rapidly soak upward, nor did it significantly alter the surface characteristics of the snow surface. It was very difficult to determine if oil lay beneath the surface in many places without removal of the snow cover. The odor of the diesel did pervade the surface from beneath, but detection by this method would be highly dependent upon wind conditions. The danger of unknowingly stepping into a concealed pool of oil is very real under the circumstances outlined above. Oil that had pooled adjacent to the ruptured tank was pumped directly by vaccum truck and subsequently stored in nearby steel tanks. It is estimated that 34,000 gallons (or 1/2 of the total spilled) was recovered by the vacuum truck within two days following the spill.

Released fuel that had surged over the containment dike spread for considerable distances outside the dike perpendicular to the end of the fifteen tanks. Since the dikes and gravel work area pad were essentially a frozen gravel aggregate very little penetration or damage was caused by the oil. This oil outside the dikes was recovered by bulldozer and front loaders. The bulldozers would scrape to the surface of the frozen gravel work pad and push the contaminated snow into piles. The piles were subsequently removed with front loaders directly to the

disposal pit. Areas where oil remained on the surface were reworked by covering with fresh snow and repeating the process outlined above. Sorbents were also used in the same areas after the overburden of snow was removed.

A few inches of the upper layer of the contaminated gravel work pad and accessible areas just inside the containment dike were removed for disposal. The surface consisted primarily of sand and gravel that was permeated with ice. The area inside the containment dike had been covered with blow sand from the nearby river. D-9 Caterpillar bulldozers with standard rippers were used to break up the surface of the ground. The rippers were not very effective in the ice-rich sand and gravel surface. One operator estimated that hours would be required to remove one foot of the surface from a small fraction of an acre. The rippers reportedly had to be replaced frequently.

Commercial sorbents that Atlantic Richfield Company had stockpiled at Prudhoe Bay were used to a limited extent. Both pads and rolls of sorbents were tried in areas where most of the snow had been removed. Pads of a few square feet proved unsuccessful because the wind would blow them away. The rolls of sorbent resembled felt and were actually a fiber matting made from cornstalk material produced by the 3-M Company. The sorbent came in rolls 3 or 4 feet wide and approximately 100 feet long. The long strips could readily be weighted down and tended to stay in place better than the pads. The presence of an overburden of snow over the spill would virtually negate the effectiveness of the sorbents unless the pads were pressed into the snow.

Access to the space within the containment dike between the fifteen tanks was very limited due to close spacing between tank centerlines (approximately five feet). Heavy equipment could not be used in this area and access by people was difficult. Some of the spilled diesel that entered the region between the tanks was left until spring for removal.

Storage and Disposal

Disposal of the recovered fuel, contaminated snow and debris was greatly facilitated by using an existing burn pit located less than one mile from the spill site. The burn pit was essentially a large open area of several hundred foot diameter to which an unlimited supply of natural gas was piped from the Atlantic Richfield topping plant at Prudhoe Bay. The nozzle of the burner was located 3-4 feet above the base of the pit. The flame was directed downward at an angle of approximately 30° from horizontal. The contaminated snow or sorbents were piled within a few feet on either side of the large flame which produced progressive melting of the exposed surface which flowed directly to the flame. The contaminated material piled beside the flame was periodically advanced toward the burn pit with a bulldozer.

Personal observation of the burn pit when the ambient temperature was approximately -50°F indicated the effective radius of melting was a few feet from the flame. This necessitated constant movement of the material to be burned toward the flame. No one contacted during the site visit knew the quantity of natural gas being used in the burn pit. The question is somewhat academic under the circumstances because this is excess gas that would have been flared anyway.

Oil recovered from pools with the vacuum truck was transferred directly to a steel storage tank in the immediate area. The means of ultimate disposal is not known. The fuel could presumably be reprocessed or disposed of in the burn pit.

Personnel Safety and Working Conditions

The most unique aspects of the Arctic environment during the winter that relate to working outdoors are the lack of daylight (natural lighting is adequate approximately four hours per day) and the extreme cold. The cold temperature effects are compounded with respect to personnel by the

wind chill factor. Equivalent wind chill temperatures can reach well below -100°F. The locally available equipment is adapted to the harsh environment. Personnel are accustomed to the cold because they work in the area every day. However, working around spilled diesel fuel is not a common event and the danger of frostbite was ever present. Several of the personnel working on the cleanup had diesel soak through their boots which resulted in skin reacting to the cold or the diesel fuel. Had heated vehicles and facilities not been immediately available, it could have led to frostbite.

Observations

The following observations relating to the spill summarized above are felt pertinent to handling of similar spills in the future.

1. The interconnection of several temporary storage tanks is not warranted even though filling and drainage of the tanks is facilitated. Increasing the volume of the spill due to failure of one tank is simply too great a risk. The failure of one more part* of the fuel system could have increased the spill summarized above by an order of magnitude.

2. Containment dikes should be either high enough or far enough away from storage tanks to prevent overflow by a surge.

3. Detection of spilled product beneath the snow is nearly impossible and would be further complicated by blowing snow subsequent to the spill. Any area in which the spill has been located should be staked to prepare for the eventuality that snow could cover the site. It is suggested that hydrocarbon "sniffers" be tested or developed to permit location of petroleum products beneath the snow.

4. Winter conditions in the Arctic virtually preclude large or extended manual operations for removal of the spill. Tracked

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* For instance if the relief valve had leaked after the tank ruptured. This could have broken the vacuum in the system and the nine intact tanks would have emptied.

vehicles (winterized) must be brought to the site at the earliest possible time.

5. The use of portable and combustible debris containers is highly recommended for cleanup and disposal of spills in the winter (see Appendix B of the report). Handling and cleanup of bulky, non-disposable containers is too labor-intensive. Cleanup would be especially difficult.

6. Portable pumps and pillow tanks should be rushed to the spill site so that the product can be recovered before it spreads. Pumping is clearly the most efficient method if the oil exists in pools and cannot be burned in place.

7. Disposal by burning in a pit fueled by an external source seemed to be the only viable alternative for disposal. The pit should be located down wind as close to the spill site as practicable from a safety standpoint to avoid time-consuming transfer operations.

8. The surface of dikes and upper layer of impoundments should be glazed with water during freeze-up. This will retard penetration of the spilled product into the surface in the event of a spill.

9. Personnel at the spill site wearing the large white inflatable "bunny boots" (Boots, extreme cold weather, MIL-B-41816, Type II, Class I) had severe problems with diesel soaking through to their feet. The fuel apparently dissolved or passed through the seams of the rubber boots. It is strongly recommended that the Coast Guard test all items of Arctic survival clothing (particularly boots) that will be issued to cleanup teams in Alaska to determine the effect of exposure to oil. Gloves, mittens or any article of clothing with down insulation should have an outer surface relatively impermeable to petroleum

products. One case of frostbite leading to amputation of three fingers occurred earlier at Prudhoe Bay when an individual picked up a set of tools that had spilled from a pickup truck and been soaked with diesel in the process. The diesel rendered his down-filled gloves completely ineffective.